Hydrogeomorphic Evaluation of Ecosystem Restoration and Management Options for Tewaukon National Wildlife Refuge

Prepared For:

U. S. Fish and Wildlife Service
Region 6
Lakewood, Colorado

Greenbrier Wetland Services
Report 14-05

Mickey E. Heitmeyer
Cary M. Aloia

June 2014

HYDROGEOMORPHIC EVALUATION OF ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS FOR TEWAUKON NATIONAL WILDLIFE REFUGE

Prepared For:

U. S. Fish and Wildlife Service
Region 6
134 Union Blvd.
Lakeland, CO 80228

By:

Mickey E. Heitmeyer
Greenbrier Wetland Services
Rt. 2, Box 2735
Advance, MO 63730

and

Cary M. Aloia
Wetland Dynamics
3393 E CR 9 S
Monte Vista, CO 81144

JUNE 2014

Greenbrier Wetland Services
Report No. 14-05

Mickey E. Heitmeyer, PhD
Greenbrier Wetland Services
Route 2, Box 2735
Advance, MO 63730
www.GreenbrierWetland.com

Publication No. 14-05

Suggested citation:

Heitmeyer, M. E., and C. M. Aloia. 2014. Hydrogeomorphic evaluation of ecosystem restoration and management options for Tewaukon National Wildlife Refuge. Prepared for U. S. Fish and Wildlife Service, Region 6, Lakeland, CO. Greenbrier Wetland Services Report 14-05, Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

Photo credits:

COVER: Jack Lalor, Tewaukon NWR staff

Tewaukon NWR refuge staff; USFWS, http://digitalmedia.fws.gov

This publication printed on recycled paper by

CONTENTS

Hollingsworth, USFWS

Al Sapa, USFWS

EXECUTIVE SUMMARY

This report provides a hydrogeomorphic (HGM) evaluation of ecosystem restoration and management options for the Tewaukon and Sprague Units of Tewaukon National Wildlife Refuge (NWR) and the Hartleben, Gunness, Biggs, Bladow, Aaser, and Prochow Waterfowl Production Areas (WPA). These WPAs are collectively referred to as the Hartleben WPAs. Objectives of the report are:

1. Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Tewaukon NWR region.
2. Document changes in the Tewaukon NWR regional ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
3. Identify restoration and management options incorporating ecological attributes needed to restore specific habitats and conditions within Tewaukon NWR and the Hartleben WPAs.

Information was obtained on historical and contemporary geology and geomorphology, soils, topography, climate and hydrology, and plant and animal communities of the Tewaukon NWR region. The Tewaukon NWR and Hartleben WPAs are located in the glaciated Drift Plain and Lake Agassiz Plain ecoregions and the surficial geomorphology of the region has been influenced by the advance and retreat of many glaciers along with the historical formation and decline of pro-glacial Lake Agassiz. The study areas contain 89 distinct soil types. Soils in the Lake Agassiz Plain are primarily heavy clay loams while those in the Drift Plain are dominated by silt loams. Soil type distribution reflects both historical parent material and processes along with position on hill slopes, valleys, and depressions. The refuge and WPA region is characterized by gently rolling hills marked by distinctive prairie pothole wetland depressions and a few larger relict glacial lakes.

The Tewaukon NWR region receives about 19 inches of precipitation per year with strong seasonal patterns of rain and snowfall. The average growing season is about 130 days. Long-term precipitation patterns indicate regularly alternating wet vs. dry periods with peak-to-peak intervals recurring at about 30-year intervals. Refuge and WPA lands are within the Sheyenne, Red River of the North, and Wild Rice River watersheds. Tewaukon NWR receives water from the Wild Rice River, which runs through the Sprague and Tewaukon units, along with several small tributary creeks. Tewaukon NWR is considered a "flow-through" refuge where Wild Rice River water enters from the west and south, fills various wetlands and impoundment pools, flows into and fills Lake Tewaukon, and then overflows back into the Wild Rice channel that discharges north eventually to the Red River. Seasonal peak flows in the Wild Rice River usually occur in April when snow melts and regional precipitation increases. Groundwater aquifers underlie Tewaukon NWR and the Hartleben WPAs and receive water infiltrating from surface water sources and they also discharge water into some low elevation wetland depressions.

Tewaukon NWR and the Hartleben WPAs are within the Cold Temperate Grasslands Biotic Region and includes tallgrass prairie in the eastern Lake Agassiz Plain that trends toward mixed-grass prairie in the western Drift Plain. Prairie areas are embedded with numerous moraine "pothole" wetland depressions. Mesic tallgrass and mixed-grass communities tend to occur on higher elevation hilltops and slopes, while wet-mesic and wet prairie/meadow communities occur on lower hill slopes and moraine valley areas. Pothole wetlands range from small temporarily flooded (Type II) to larger semipermanently flooded (Type IV) basins. Several large permanently flooded relict glacial lakes, including the namesake Tewaukon Lake, are present on and adjacent to the NWR and WPAs. A HGM matrix of potential historical communities present in the Tewaukon NWR region was prepared (Table 5) based on the combination of geomorphology, soils, topography, and hydrology. This matrix of understanding about communities was then used to map the potential historical distribution of vegetation communities at Tewaukon NWR and the Hartleben WPAs (Fig. 22).

The historical and more contemporary changes to the Tewaukon NWR region, and specific refuge and WPA lands, are chronicled in this report including discussion of early settlement and land use changes, contemporary hydrologic and vegetation community changes, and refuge/WPA development and management. The primary ecosystem changes that need to be addressed for future restoration and management goals on these lands are: 1) extensive conversion of tall and mixed-grass prairie and interspersed pothole wetland basins to agricultural uses; 2) change in regional surface and groundwater flow patterns and wetland/river hydrology from land conversion, field tiling, draining of wetlands, and water- and flood-control infrastructure; 3) suppression of fire and changes to native herbivory patterns in the prairies; and 4) introduction and expansion of many invasive and non-native species of plants.

Based on the HGM context of information obtained in this study, we believe that future conservation efforts at Tewaukon NWR and the Hartleben WPAs should seek to:

1. Maintain and restore the physical and hydrological character of lands within the Wild Rice River watershed, especially in the Tewaukon Wetland Management District (WMD).
2. Restore the natural topography, physical integrity of water flow patterns, and water regimes in prairie, relict glacial lakes, and prairie potholes on the Tewaukon NWR and WPAs.
3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relationship to topography and geomorphic landscape position.

The report offers specific recommendations to help address each of the above conservation goals. For #1, they include:

- Slow and reduce surface water, sediment, and nutrient runoff into the Wild Rice River and through Tewaukon NWR by delineating sub-basin areas that contribute the most, or are at the highest potential risk of contributing sediment, nutrient, and surface water runoff into Tewaukon NWR and then targeting soil and water conservation practices to these areas. Natural drainage corridors in the Tewaukon WMD should also be restored or modified where possible.
- Convert marginal, highly erosive, lands to native vegetation and wetlands by promoting acquisition of more WPAs and wetland and grassland easements, protecting all native prairies and restoring prairie to highly erodible hill slopes, restoring broad water flow patterns through moraine drainages, and restoring wetland depressions.

For #2, they include:

- Restore the physical and hydrological character of prairie pothole wetlands on USFWS fee-title lands. This will require that a complete inventory of all wetlands on USFWS lands be conducted to identify individual local watersheds, type and degree (if any) of alterations including ditches or topography modifications, and respective hydrological regimes. If a wetland can function as is on its own, it should not be modified and should be protected. If alterations are present, hydrology restoration should occur by removing, modifying, or plugging drainage ditches, removing old tile drainage systems, and restoring basin bathymetry. Large basins may require installation of water-control structures to allow storage and management of surface and groundwater discharge into the basin. Native prairie vegetation should be restored on upland slopes draining to the potholes.
- Restore the physical and hydrological character of larger relict glacial lakes and larger wetland basins. This restoration will require an assessment of current conditions along with the historical community state and determining topography, water flow and management, and vegetation remediation. These larger

wetlands should be managed for more natural seasonal and long-term water regimes where possible to emulate alternating wet and dry patterns of flooding and drying.

For #3, they include:

- Restore native mesic and wet-mesic tallgrass and mixed-grass prairie on upland moraine hill slopes.
- Restore wet prairie/meadow communities in moraine valleys and drainages and along the edges of larger wetlands.
- Restore natural wetland vegetation zones in prairie potholes.
- Restore natural wetland vegetation zones in larger relict glacial lakes
- Maintain small bands of riparian woodland around parts of Lake Tewaukon, areas along the Wild Rice River, and along the LaBelle Creek corridor.

Future management of Tewaukon NWR and the Hartleben WPAs should include regular monitoring and directed studies to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Further, future management on these lands should be done in an adaptive management framework where predictions about community response and water issues are made and then follow-up monitoring is conducted to evaluate ecosystem responses to the action. Critical information and monitoring needs include:

- Quantity and quality of surface and groundwater discharges and runoff throughout the Wild Rice River watershed
- Success and methods of restoring natural water regimes and water flow patterns
- Long-term changes in vegetation and animal communities

Keith Frankki, refuge staff

Jack Lalor, refuge staff

Jennifer Jewett, refuge staff

INTRODUCTION

The Tewaukon National Wildlife Refuge (NWR) Complex includes the Tewaukon NWR and the Tewaukon Wetland Management District (WMD) located in the Northern Basin of the Red River Valley and adjacent glacial Drift Plain in Ransom, Richland, and Sargent Counties in southeastern North Dakota (Fig. 1). Tewaukon NWR includes two units, Tewaukon and Sprague Lake that contain a combined 8,363 acres in Sargent County. Tewaukon WMD includes 106 waterfowl production areas (WPAs) totaling 14,159 acres, 590 wetland easement contracts that protect 34,824 wetland acres, 23 grassland easement contracts on 10,757 acres, and two Easement Refuges (Storm Lake and Wild Rice Lake) that contain 1,466 acres (U.S. Fish and Wildlife Service (USFWS) 2000).

The history of the Tewaukon NWR Complex began when land around Lake Tewaukon and three USFWS Easement Refuges were established at Lake Elsie, Wild Rice, and Storm Lake in 1934 by Executive Order 6910, which provided for acquisition of easements for flowage and refuge purposes and filing of water rights (USFWS 2000). The first fee-title acquisition was an 80-acre tract obtained in 1936. The USFWS subsequently divested Lake Elsie in 1998. Tewaukon NWR was established in 1945 by Executive Order 9337, Public Land Order 286, and the Migratory Bird Conservation Act. The authorizing purpose of the refuge in 1945 was primarily "… for use as inviolate sanctuary or for any other management purpose, for migratory birds." Tewaukon NWR was part of the Sand Lake NWR complex until 1956 when the Tewaukon NWR became fully staffed and administered as a separate NWR (USFWS 2000). Tewaukon NWR includes lands set aside as the Lake Traverse Indian Reservation, established in 1867 for the Sisetonwan and Wahpetonwan peoples, and encompass a portion of historic Lake Tewaukon, a natural glacial lake. A major feature of Tewaukon NWR is the Wild Rice River, a tributary to the Red River, which flows through the Sprague Lake and Tewaukon units (Fig. 2). Tewaukon WMD was established in 1960 by Public Law 85-585, the Migratory Bird Hunting and Conservation Stamp Tax, North American Wetlands

Figure 1. General location of the Tewaukon National Wildlife Refuge Complex in Ransom, Sargent, and Richland counties, North Dakota (from USFWS 2000).

Conservation Act, and the Farmers Home Administration (Striffler 2013; USFWS 2000).

The prairie dominated landscape at the Tewaukon NWR Complex has experienced many changes from the 1800s including conversion of prairie and wetland basins to agricultural uses, surface drainage and altered hydrological regimes, introduction of invasive and nonnative plants, contamination and siltation of regional rivers and wetlands, and alteration of system disturbance processes such as native herbivory, fire, and flooding and drying regimes. Water-control and land management on refuge lands also have affected natural communities and ecological processes. In 2000, a Comprehensive Conservation Plan (CCP) was prepared for the Tewaukon NWR, which identified management goals and habitat/wildlife objectives for a 15-year planning horizon (USFWS 2000). Since that time, refuge management has sought to implement CCP goals, but also recognized constraints of water-control capabilities and the need for more holistic system-based approaches to future restoration and management efforts.

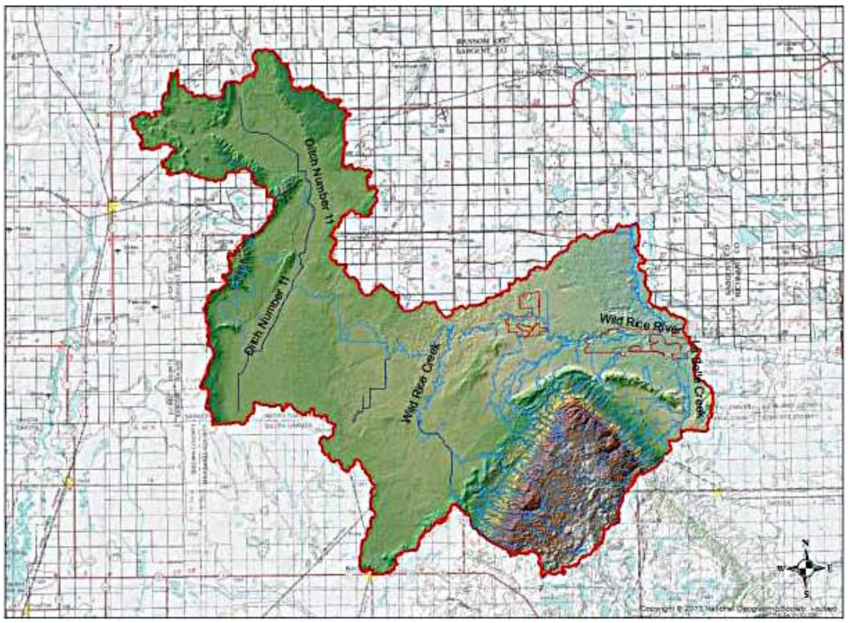


Figure 2. Major rivers, streams, and ditches in the Wild Rice River watershed (from Striffler 2013).

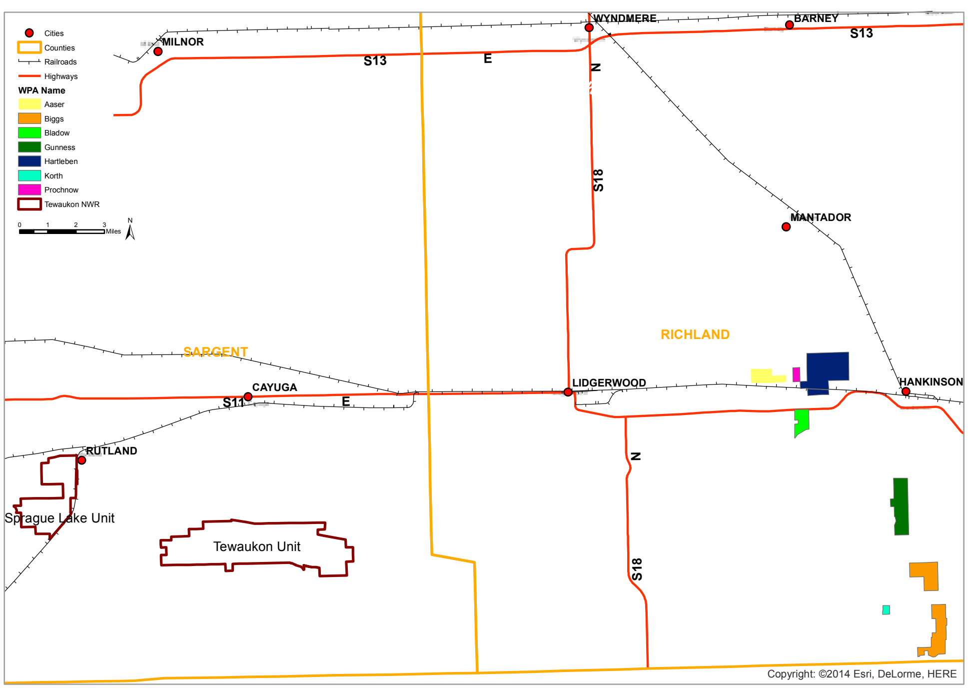


Figure 3. Location of Tewaukon National Wildlife Refuge and the Hartleben WPA Complex sites evaluated in this HGM report.

This report provides a hydrogeomorphic (HGM) evaluation of Tewaukon NWR and the Hartleben, Gunness, Biggs, Korth, Bladow, Aaser, and Prochow WPAs that contain 3,654 acres in Richland County (Fig. 3). These WPAs are collectively referred to as the Hartleben WPAs and were chosen for inclusion in this HGM evaluation by refuge staff because they contain areas that are actively managed and are being considered for additional ecosystem restoration. The HGM evaluation provides data and information about historical communities and their ecological processes, along with general recommendations for ecosystem restoration and management in the region, as it specifically relates to future management of the refuge. Recently, HGM has been used to evaluate ecosystem restoration and management options on many NWR's throughout the U.S. (e.g., Heitmeyer et al. 2014, Heitmeyer and Aloia 2013). These HGM evaluations obtain and analyze historical and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrology, 5) aerial photographs and maps, 6) land cover and plant/animal communities, and 7) physical anthropogenic features of ecosystems (Heitmeyer 2007a, Klimas et al. 2009, Theiling et al. 2012, Heitmeyer et al. 2013). The HGM information provides a context to understand the physical and biological formation, features, and ecological processes of lands within a NWR and the surrounding region. This historical assessment also provides a foundation, or baseline condition, to determine what changes have occurred in the abiotic and biotic attributes of the ecosystem and how these changes have affected ecosystem structure and function. Ultimately, this information helps define the capability of the area to provide key ecosystem functions and values and identifies options that can help to restore and sustain fundamental ecological processes and resources.

Objectives of this HGM evaluation of Tewaukon NWR are:

1. Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Tewaukon NWR region.

2. Document changes in the Tewaukon NWR ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration and management options incorporating ecological attributes needed to restore specific habitats and conditions within Tewaukon NWR and the Hartleben WPAs.

Keith Frankki, refuge staff

Frank Doyle, USFWS

Keith Frankki, refuge staff

THE HISTORICAL
TEWAUKON NWR ECOSYSTEM

GEOLOGY AND GEOMORPHOLOGY

North Dakota was most recently glaciated by ice that moved south from the Keewatin Center in North Central Canada during the Wisconsin-age period (Mayewski 1981, Bluemle 1988). This ice formed the James Lobe extending into South Dakota during the late-Wisconsin period, ultimately draining the southern portion of the Laurentide Ice Sheet (Fig. 4; Carlson 2006). Sediments deposited over the past 600 million years have developed limestone, sandstone, and shale formations above the igneous Precambrian rock becoming thicker from east to west throughout North Dakota (Fig. 5). The Red River Valley (RRV) region is characterized by a surficial layer of Quarternary glacial drift underlain by basement Precambrian igneous rock (Bluemle 1988). As the glacier receded about 11,000 years ago, glacial till and glacial drift, were deposited, averaging about 100 feet in thickness. Pro-glacial Lake Agassiz covered the eastern portion of Richland County during the Pleistocene until about 9,500 years ago (Fig. 6; Larson and Schaetzl 2001; Bluemle 1979; Bluemle and Clayton 1982). The Tewaukon NWR and Hartleben WPAs are located in the Northern Glaciated Plains (hereafter called the Drift Plain) and Lake Agassiz Plain ecoregions (Fig. 7). More, specifically these areas lie in: 1) the Tewaukon/Big Stone Stagnation Moraine (also known as the Tewaukon Dead Ice Moraine, see Striffler 2013:16) that is composed of Wisconsin-age glacial till over Cretaceous Pierre shale and 2) the western edge of Beach Ridge and Sand Deltas deposits that contain stratified sand and gravel beach and strand line deposits from lacustrine silts or of sandy deltaic deposits of historic Lake Agassiz (Fig. 7).

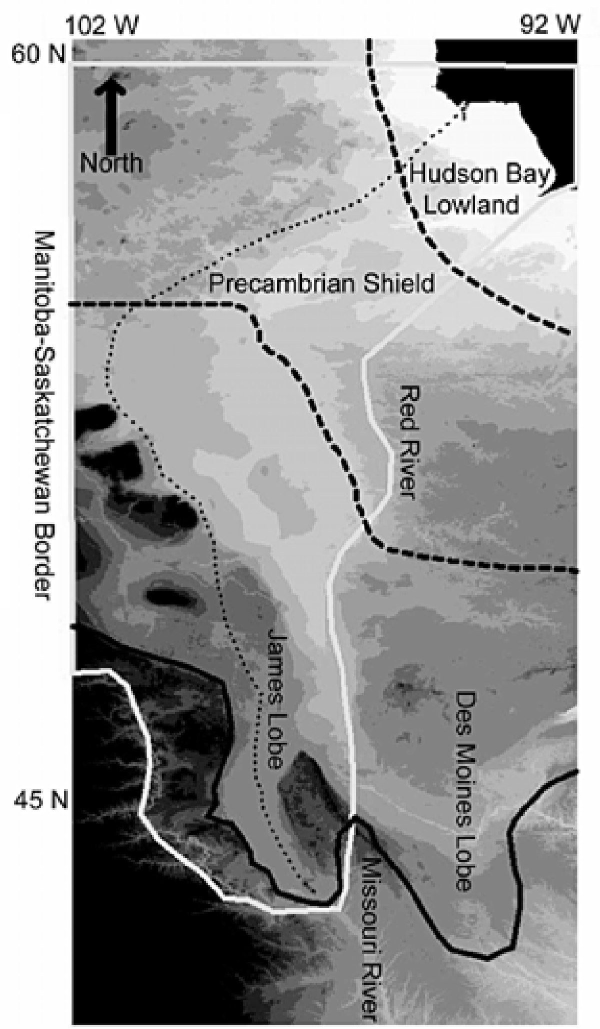


Figure 4. Map of the glacial ice James Lobe (west) and adjacent Des Moines Lobe (east) margins (solid black line) and model domain (white line) overlain on a 50m DEM. Dashed black line denotes the Precambrian Shield boundary (from Carlson 2006).

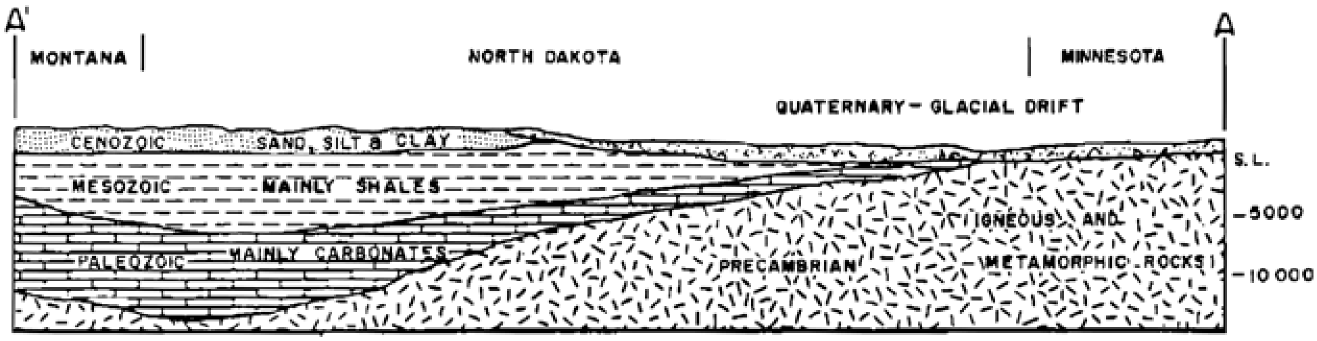


Figure 5. Geological cross-section map of the Northern Great Plains region from Montana to Minnesota (from Bluemle 1988).

The surficial geomorphology of the Tewaukon NWR complex has been significantly influenced by the advance and retreat of many glaciers along with the pro-glacial Lake Agassiz (Upham 1895). As the James Lobe advanced and retreated, rocks comprised of granite, gneiss, schist, limestone, and shale were deposited as a veneer over the low rolling prairie moraine hills and the kettle-like depressions (Bennet et al. 1908). The portion of the RRV area that was once covered by Lake Agassiz now contains a level surface with an average elevation gradient of about two feet fall/mile. The Coteau des Prairies, a glacial moraine plateau, lies directly south of the Tewaukon NWR containing the Sisseton Hills along

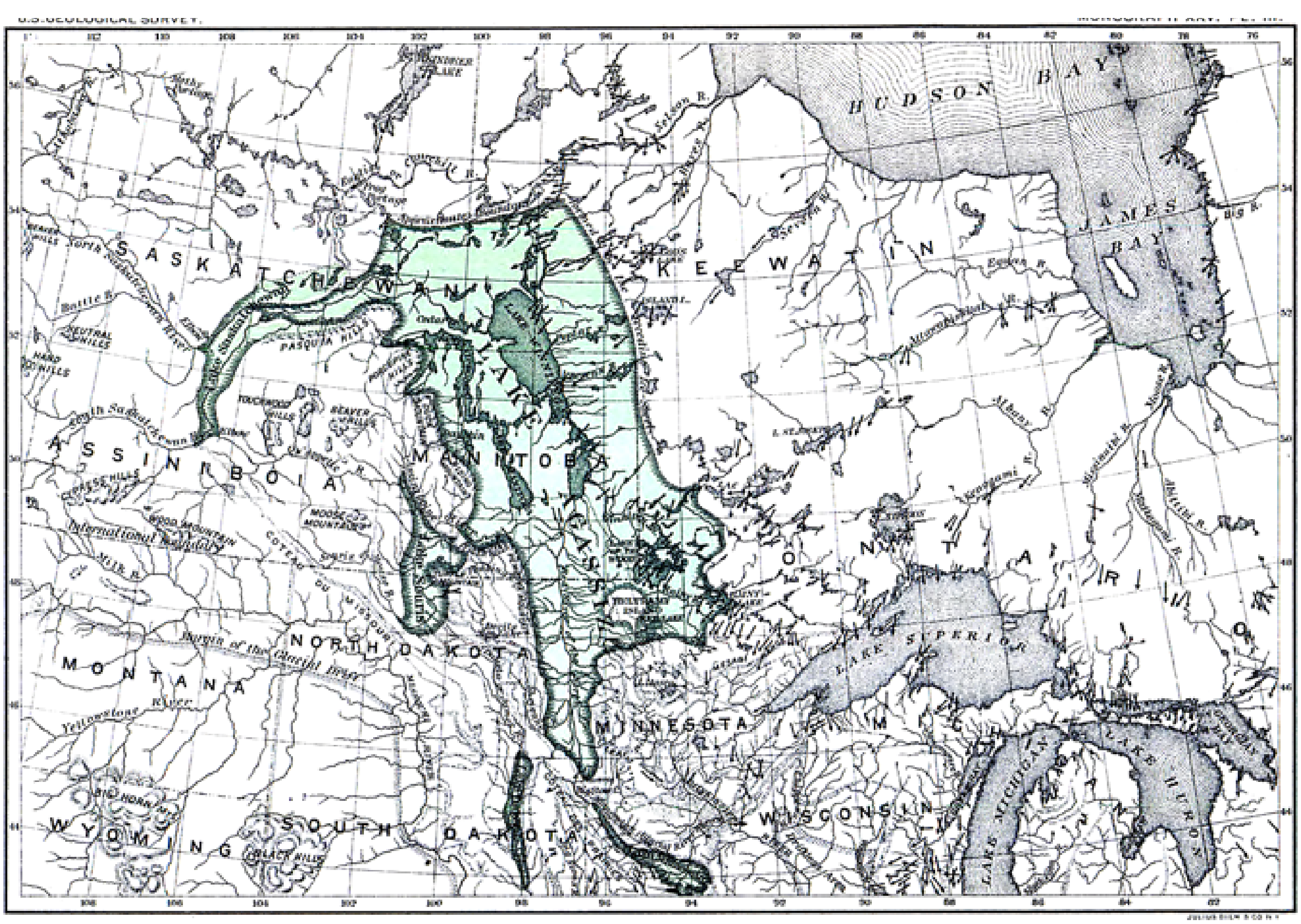


Figure 6. Location of historic Lake Agassiz and other ancient Upper Laurentian lakes (from Upham 1895).

with many drainages that flow north and east, to and around the refuge towards the Red River (Hutton et al. 1920).

SOILS

The Tewaukon NWR and the Hartleben WPAs contain 89 distinct soil types (Fig. 8). A total of 31 soil types are present on Tewaukon NWR in Sargent County and 58 soil types are present on the Hartleben WPAs in Richland County (SCS 1964, Thompson and Joos 1975). Soils in the historic Agassiz Lake Plain are primarily heavy clay loams while those of the glaciated Drift

Figure 7. Environmental Protection Agency designated ecoregions in North Dakota (available at http://www.epa.gov/web/pages/ecoregions/level_iii_iv.htm).

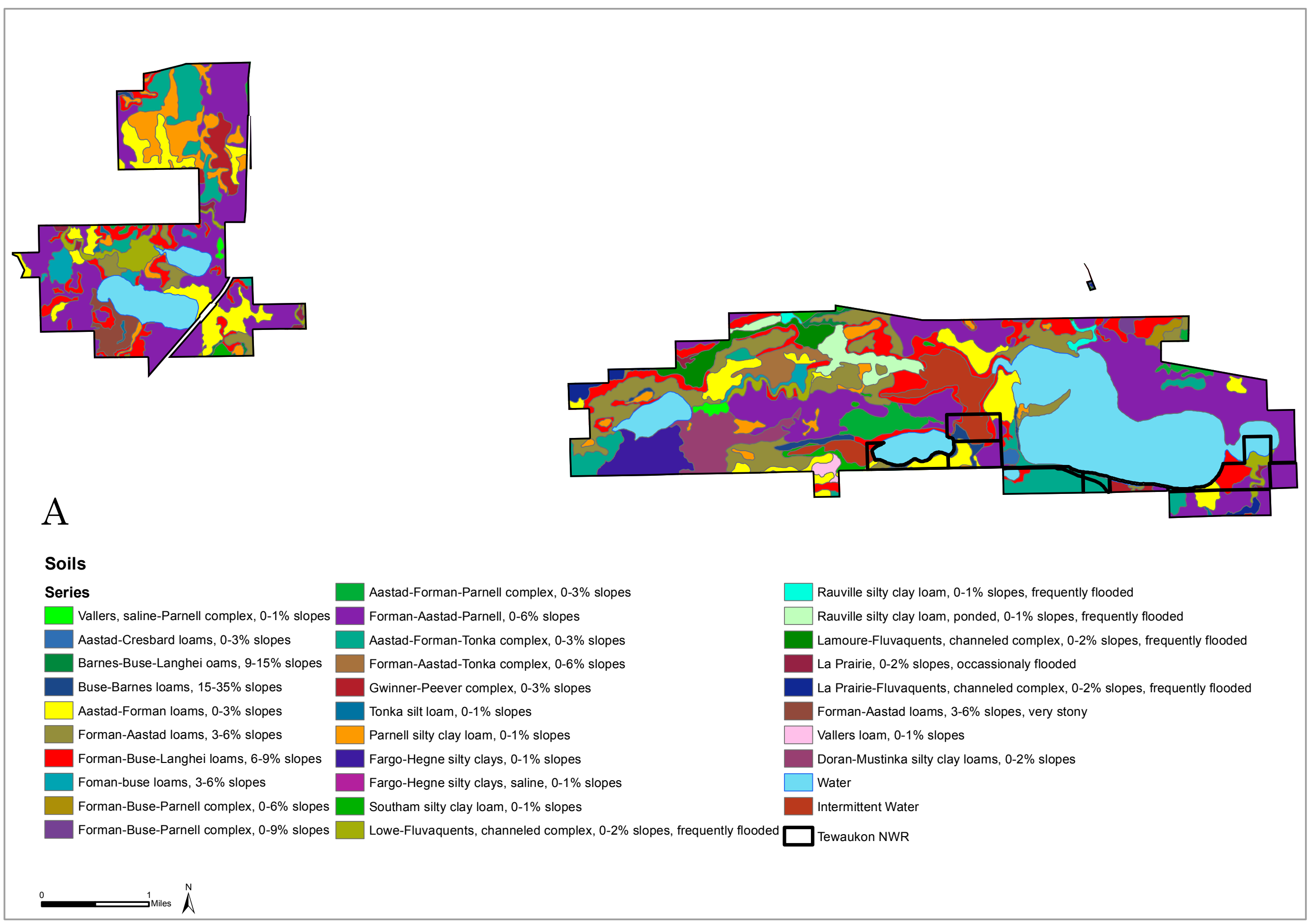


Figure 8. Soils on: a) Sprague Lake and Tewaukon National Wildlife Refuge units; b) Hartleben, Aaser, Prochnow, and Bladow WPAs; and c) Biggs, Gunness, and Korth WPAs (available at http://soildatamart.nrcs.gov).

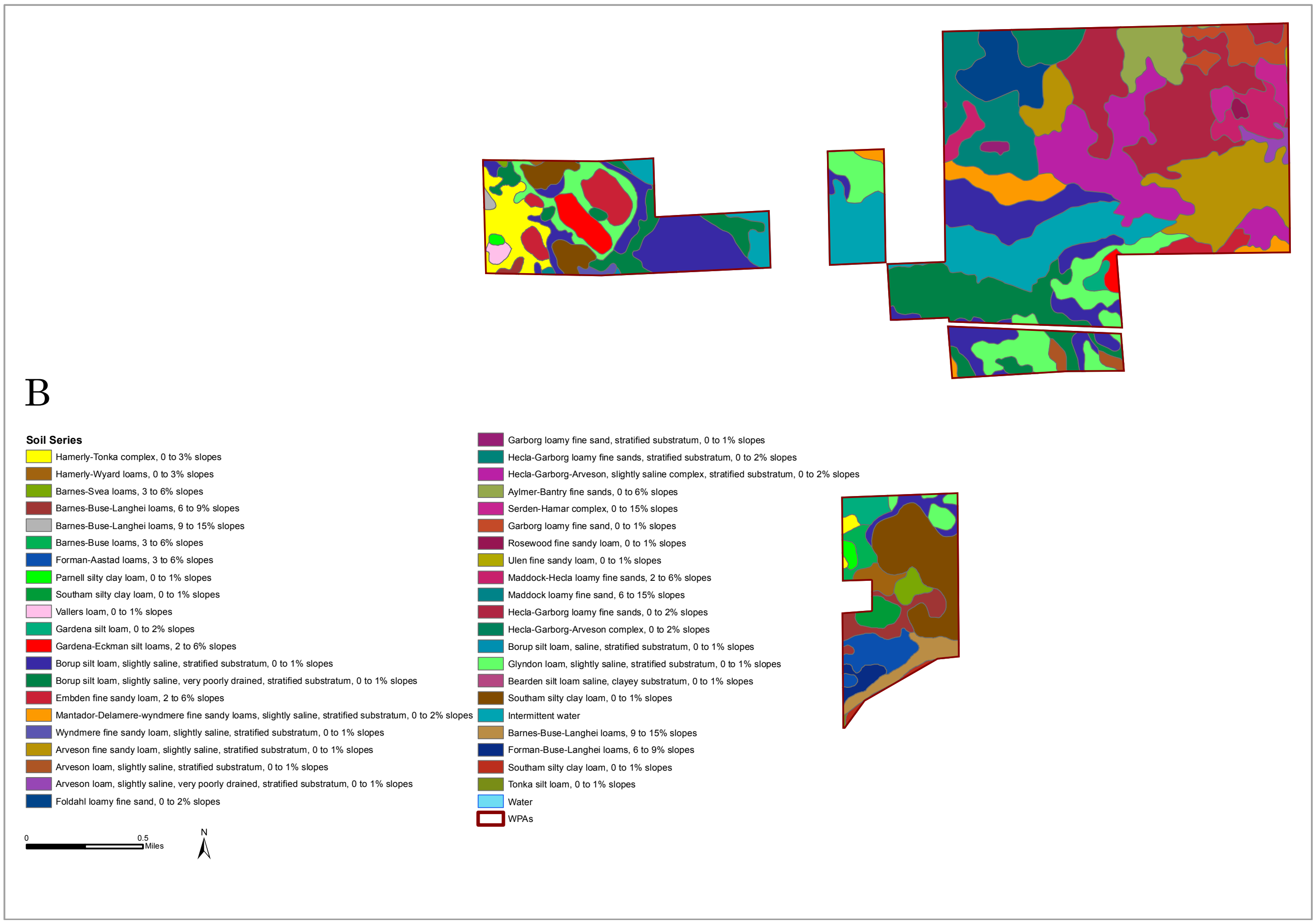


Figure 8, continued. Soils on: a) Sprague Lake and Tewaukon National Wildlife Refuge units; b) Hartleben, Aaser, Prochnow, and Bladow WPAs; and c) Biggs, Gunness, and Korth WPAs (available at http://soildatamart.nrcs.gov).

Plain are dominated by silt loams. Beach ridges in the Agassiz Lake Plain are characterized by sandy loams (Baker 1967). The WPAs in Richland County contain predominantly Fargo-Ryan association (FR) soil types that were formed in the ancient Lake Agassiz lacustrine sediments. The FR association is typically characterized by nearly level, poorly-drained, fine-textured and moderately fine textured soils, some of which are very shallow over sodic claypan subsoils (Thompson and Joos 1975). The FR association consists primarily of silty clay soils with the Ryan soils containing high concentrations of sodium salts. This soil occurs on lake plains that are nearly level except along streams and drainages where it becomes steeper. Tewaukon NWR contains mostly the Forman-Aastad (FA) soil-land association formed in glacial till. The FA association is typically characterized by well drained and moderately well drained, nearly level and undulating soils in loamy glacial till with prismatic-blocky subsoil (SCS 1964). This association consists primarily of dark loam soils that are distributed based partly on location within the undulating topography. Forman, Barnes, Svea, Maddock, Langhei and Buse soils are well drained loams located on upper slopes while the Aastad, Hecla, Gardena, Garborg, Eckman, and Lowe are moderately well drained and located on the lower slopes (Fig. 9, SCS 1964). Soils in hill valleys and depressions include Parnell, Southam, Borup, Arveson, Ulen, Tonka, Vallers, and Rauville soils; most of which are silty clay loam types. Lamoure soils occupy natural levee areas along the Wild Rice River.

TOPOGRAPHY

The Tewaukon NWR Complex region is characterized by a level to gently rolling landscape marked by the distinctive prairie pothole wetland depres-

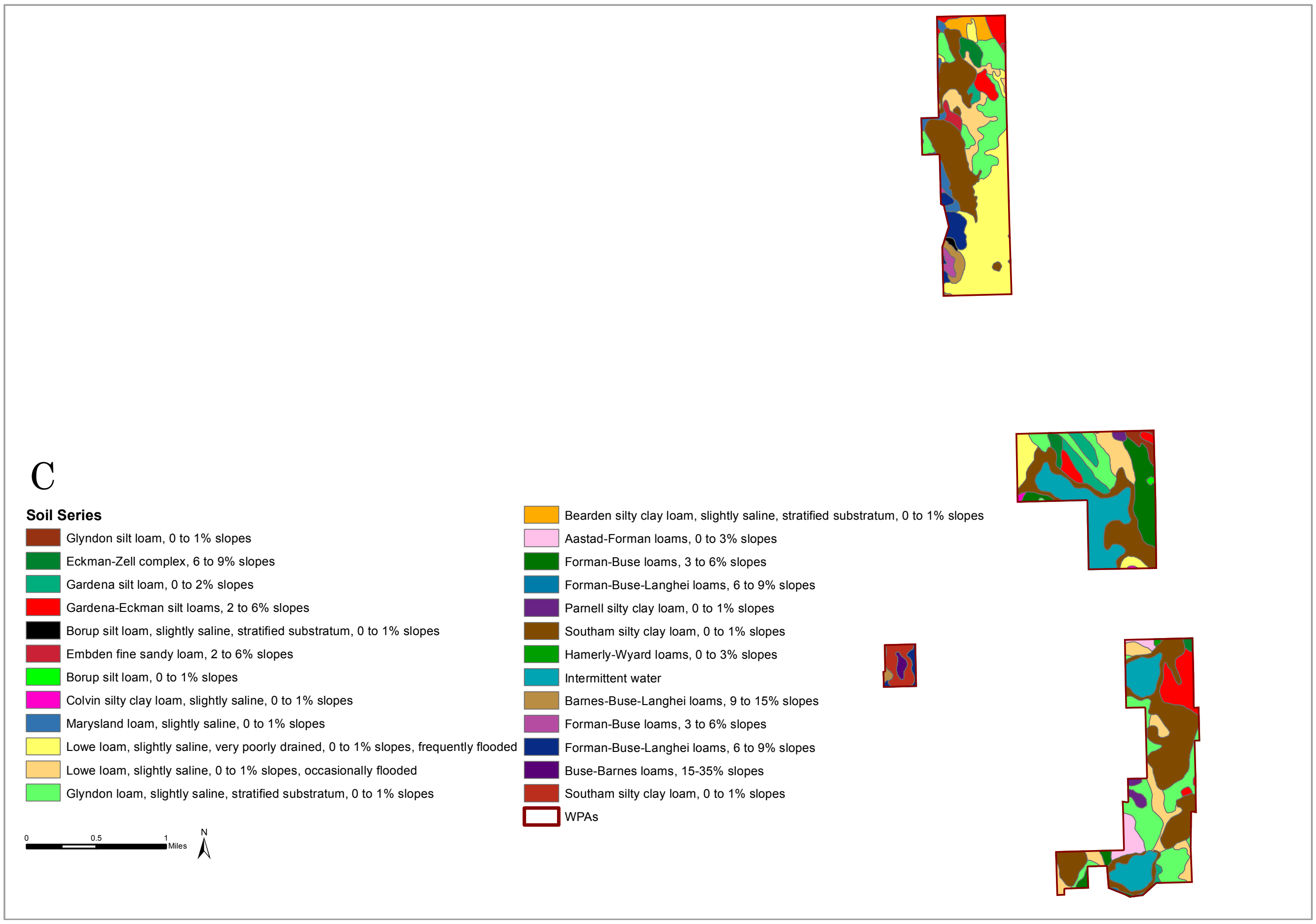


Figure 8, continued. Soils on: a) Sprague Lake and Tewaukon National Wildlife Refuge units; b) Hartleben, Aaser, Prochnow, and Bladow WPAs; and c) Biggs, Gunness, and Korth WPAs (available at http://soildatamart.nrcs.gov).

sions. Tewaukon NWR lands range from 1,142 feet above mean sea level (amsl) in the northeast corner of Tewaukon NWR to about 1,236 feet amsl at the southwest corner of Sprague Lake (Fig. 10). Just south of Tewaukon NWR, the Coteau des Prairies rise to over 1,827 feet amsl. Generally elevations throughout the Tewaukon NWR Complex decrease from west to east, and south to north. During the last glaciation and retreat of the James Lobe, moraines and kettle lakes or potholes formed along with beach ridges and deltas created as Lake Agassiz receded. Relief within the glacial drift plain may be 50 to 75 feet (Baker 1967) and pothole-type wetlands occur within glacial depressions (as can be seen in an old aerial photo, Fig. 11). Sand dunes exist near Hankinson formed at the edges of pro-glacial Lake Agassiz reaching 75 feet above the lake plain (Baker 1967). The Red River and its tributaries may be entrenched in the lake plain up to 40 feet. The historic floodplains of the Wild Rice River and its tributaries contain relict scour and deposition surfaces related to historic fluvial dynamics such as natural levees, abandoned channels, and oxbow lakes on floodplains.

CLIMATE AND HYDROLOGY

The climate of the Tewaukon NWR and WPA area is generally described as mid-continental transitioning between the semi-arid West and moist East (Striffler 2013). Regionally the Northern Great Plains Prairie Pothole Region (PPR) is affected by air masses from three locations: the Continental Polar, Maritime Tropical, and Maritime Polar (Millett et al. 2009). The Tewaukon NWR area is influenced by the relatively flat RRV where a warm ridge exists along the North Dakota and Minnesota state boundary (http://www.npwrc.usgs.gov/resource/habitat/climate/temp.htm).

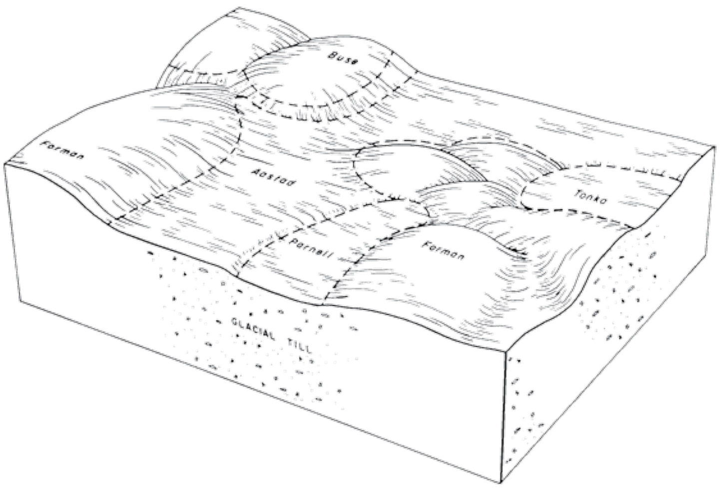


Figure 9. Distribution of select soils in relation to landscape topography in southeast North Dakota (from Thompson and Joos 1975).

Mean annual low and high temperatures in the Tewaukon NWR region are 36° and 55° Fahrenheit, respectively. Temperature lows below zero Fahrenheit can be expected each year (Table 1). Regional temperatures were much cooler prior to 1890 with a fairly drastic change occurring at that time (Rannie 1998). Prior to 1890, freeze-up dates were about a week earlier and ice break-up days were about two weeks later. The average growing season at Lisbon, 34 miles from Tewaukon NWR is about 130 days from mid-May through mid-September although frosts have been documented in every month of the year (Bennet et al.1908). Prevailing winds usually are from the south-southeast and north-northwest (Goden and Goden 2002).

The Tewaukon NWR region receives about 19 inches of precipitation per year (Table 2) with most rainfall occurring in June, averaging four inches annually (Striffler 2013). Typically less than one foot of snow occurs per month from December through February. The PPR lies within the normal pathway

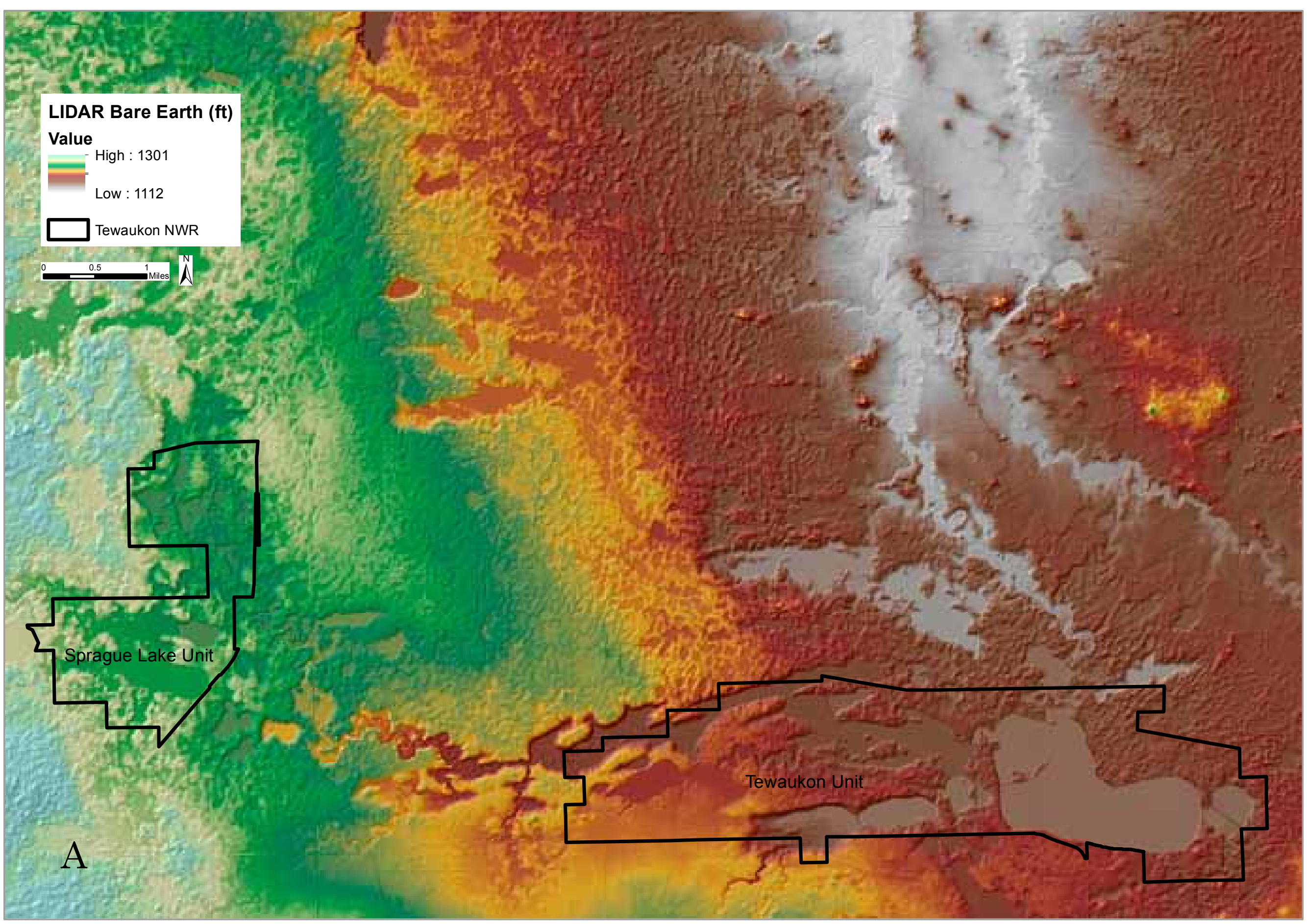


Figure 10. LiDAR 1m DEMs for a) Sprague Lake and Tewaukon National Wildlife Refuges and b) Hartleben complex WPAs.

of Arctic storms originating in the Rocky Mountains of Alberta that provides an annual average of 30 inches of snowfall (Baker and Paulson 1967; Rannie 1998). The long-term trends of precipitation and temperature are gradually increasing across the PPR (Millett et al 2009). North Dakota currently has been in a wet cycle for two decades preceded by wet cycles in the 1940s through the 1960s (Striffler 2013; Rannie 1998). From the mid 1700s to the early 1900s, there were 11 periods of drought lasting greater than 10 years and nine wet periods of greater than 10 years in the Bismarck, North Dakota area (Isenberg 1993). Similar to precipitation peaks, dry years can be expected to recur at about 30 year intervals (Fig. 12). Typically the runoff ratio (runoff + precipitation) is only about 3 to 7% of precipitation with a long term average of 90% evapotranspiration related to precipitation (Rannie 1998).

Tewaukon NWR Complex lands are within several river watersheds including the Sheyenne, Red River of the North, and Wild Rice River. The Wild Rice, Sheyenne, Goose, and Pembina rivers are the main tributaries to the Red River, which ultimately flows north to Hudson Bay. The Hudson Bay system drains approximately 40,000 mi^2 of the United States, of which approximately 20,000 mi^2 are in North Dakota (Winter et al. 1984). The headwaters of the Wild Rice River originate in the Sisseton Hills of south-central Sargent County draining north and east towards Lake Tewaukon. The Wild Rice River watershed is approximately 2,200 mi^2 (Fig. 13). Drainage resulting from the proglacial Lake Agassiz historically flowed southwest in South Dakota through the current channel of the Bois de Sioux River (Baker 1967). Water now flows to the north through the Wild Rice River drainage, which joins the Red River at Wahpeton, North Dakota.

Tewaukon NWR receives water from the Wild Rice River, LaBelle Creek and three unnamed tributaries that flow into White Lake, Hepi Lake, and Sprague Lake (Fig. 14). The Wild Rice River includes the large Ditch No. 11 system in the west and merges with the Wild Rice Creek about four miles west of the Sprague Lake Unit (Fig. 2). Then, the Wild Rice River flows east through the Sprague Lake and Tewaukon Units and through some WPAs to the Red River of the North. Tewaukon NWR is considered a river "flow-through" refuge (USFWS 2000) where water enters from the west and south, fills various wetlands and impoundment pools, flows into and fills

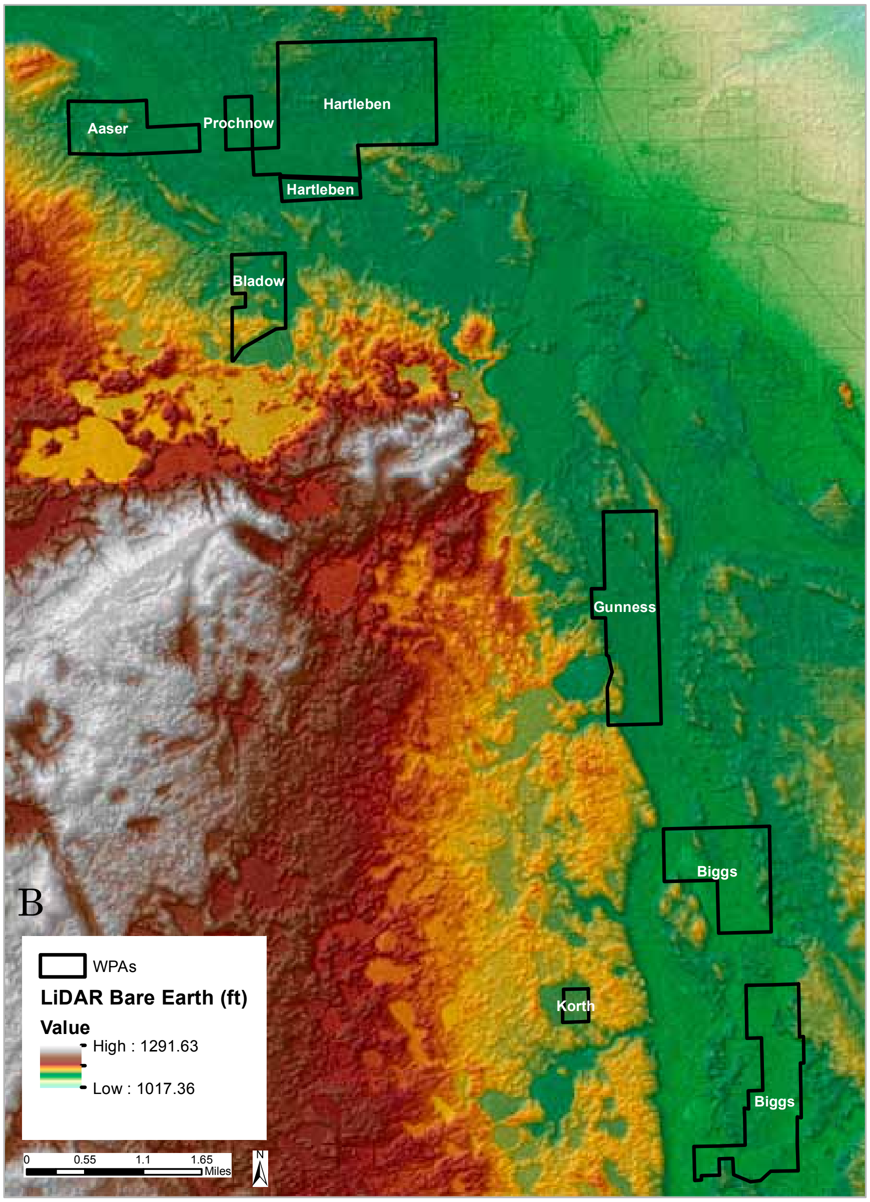


Figure 10, continued. LiDAR 1m DEMs for a) Sprague Lake and Tewaukon National Wildlife Refuges and b) Hartleben complex WPAs.

Figure 11. Historical aerial photograph of the Prairie Pothole Region in southeast North Dakota (from Tewaukon National Wildlife Refuge files – date unknown).

Lake Tewaukon, and then overflows back to the Wild Rice River channel that discharges north.

Seasonal peak flows in the Wild Rice River usually occur in April when snow melts and regional precipitation increases (Striffler 2013). Small river peaks also occur occasionally in July following large thunderstorm events. Stage-discharge relationships for the Wild Rice River near Rutland indicate the relative frequency of stream discharge and flood events (Fig. 15). These data indicate that a 100-year recurrence flood event is near 10,000 cfs, a 10-year flood event is slightly above 2,000 cfs, and discharges of over 1,000 cfs, which cause local flooding to occur every 2-5 years. A 10-foot river stage at Rutland occurs at about 1,300 cfs, and river stages near or above this level has occurred six times since 1997. When the Wild Rice and larger Red River watershed is wet, regional wetlands are full, groundwater infiltration and discharge is high, snowpack typically is high, and rains in May and June are higher, which collectively overwhelm existing flood-control infrastructure in the Red River watershed and cause flooding north to Fargo and beyond (Strobel 1996). Historically, flooding along the Red River in North Dakota occurred fairly often prior to 1900, with the largest flood recorded since 1897 at 85,000 ft^3/s (Miller and Frink 1984). During wet cycles, floods may be 2 to 4 times larger than during dry cycles.

The PPR may be extremely sensitive to changes in climate given its location at a transition area between humid and arid regions and the somewhat normal occurrence of large floods in relation to local conditions of snowmelt and summer thunderstorms (Rannie 1998). In the PPR, average temperatures have risen over the past few decades with largest increases in winter months (excepting the winter of 2013-14). Both average minimum and maximum temperatures are increasing with greater increase in average minimums (U.S. Global Change Research Program 2012). Temperatures in North Dakota are projected to increase 6-10 degrees F in the next century, which offsets projected increases in precipitation forecast for the region and would cause higher soil temperatures and increased groundwater use. Groundwater recharge projections vary widely from minus 80% to a 35% increase (Crosbie et al. 2013), but recharge increases are expected in the PPR and decreases are expected further south in the Southern High Plains of Nebraska, Colorado, Oklahoma and Kansas. Climate change assessment by the U.S. Bureau of Reclamation suggest that the Missouri River Basin, west of Tewaukon NWR likely will include: 1) temperature increases of 5-6 degrees F during the 21st Century, 2) annual precipitation will remain variable with increases of 0.7 to 7.3% by 2050, 3) mean annual surface water runoff will increase by up to 9.7%, and 4) winter rains at lower elevations will increase winter surface water runoff and decrease corresponding summer runoff (Striffler 2013:37).

Groundwater aquifers throughout North Dakota are comprised of sandstone and limestone confined by beds of shale and siltstone (Winter et al. 1984). Five bedrock aquifers are present and are overlain by glacial drift (Fig. 16) with groundwater flows trending east northeast towards the RRV. Due to high hydraulic head, groundwater discharges to overlying formations and thus to the surficial glacial drift. Glacial drift aquifers are characterized as surficial or buried. Surficial aquifers are unconfined, recharged by precipitation, and represent local water tables. Buried aquifers are confined, recharged by leakage from adjacent rocks, and contain artesian pressure. The Spiritwood Aquifer occurs in portions of the Tewaukon NWR Complex and may be defined as a buried aquifer formed by the deposition of sediments within belts of multiple channels or as buried valleys originating as glacial lake spillways (Fig. 17, Proce et al. 2004; Kehew and Boettger 1986; Winter et al. 1984). The Sheyenne Aquifer represents

Table 1. Temperature data from 1971-2000 at Lisbon, North Dakota (from National Climatic Data Center, www.ncdc.noaa.gov).

Temperature (˚F)																					
Mean (1)				Extremes										Degree Days (1) Base Temp 65		Mean Number of Days (3)					
Month	Daily Max	Daily Min	Mean	Highest Daily(2)	Year	Day	Highest Month(1) Mean	Year	Lowest Daily(2)	Year	Day	Lowest Month(1) Mean	Year	Heating	Cooling	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
Jan	17.0	-3.3	6.9	60	1987	13	22.7	1990	-41	1972	15	-8.0	1982	1805	0	.0	.0	.1	24.9	31.0	17.8
Feb	23.9	3.7	13.8	68+	1958	26	27.7	1987	-39	1982	5	-3.2	1979	1433	0	.0	.0	1.2	17.8	27.7	11.2
Mar	36.1	16.6	26.4	82	1946	28	35.9	2000	-28	1980	1	18.0	1996	1198	0	.0	.0	5.0	9.2	28.0	3.6
Apr	54.7	29.4	42.1	99	1980	21	49.1	1987	-1	1936	7	33.2	1979	689	1	.0	.3	20.5	1.0	17.6	.1
May	69.1	42.7	55.9	107	1934	31	63.6	1977	14	1946	12	47.5	1979	310	28	.0	.7	29.7	.0	3.6	.0
Jun	78.2	52.4	65.3	105	1933	20	73.9	1988	30	1953	6	60.5	1982	85	93	@	3.1	30.0	.0	.0	.0
Jul	83.6	57.4	70.5	113	1936	7	75.4	1983	34+	1985	3	63.8	1992	29	199	.5	6.4	31.0	.0	.0	.0
Aug	82.5	54.7	68.6	110	1965	13	76.0	1983	32+	1987	31	63.0	1977	55	166	.6	5.8	31.0	.0	@	.0
Sep	71.3	42.8	57.1	104+	1983	3	63.9	1998	18+	1965	26	51.9	1975	263	25	.1	1.6	29.4	.0	3.1	.0
Oct	57.7	31.1	44.4	92+	1992	2	49.4	1973	0	1936	26	39.3	1976	638	0	.0	.1	23.8	.4	15.5	.0
Nov	36.7	17.5	27.1	76	1965	2	38.4	1999	-27	1950	27	15.9	1985	1137	0	.0	.0	5.3	10.8	27.9	2.1
Dec	22.9	3.6	13.3	70	1950	6	26.8	1999	-37	1967	31	-2.4	1983	1606	0	.0	.0	.5	22.1	30.8	11.8
Ann	52.8	29.1	41.0	113	Jul 1936	7	76.0	Aug 1983	-41	Jan 1972	15	-8.0	Jan 1982	9248	512	1.2	18.0	207.5	86.2	185.2	46.6

+ Also occurred on an earlier date(s)

@ Denotes mean number of days greater than 0 but less than .05

Complete documentation available from: www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

Issue Date: February 2004 054-A

(1) From the 1971-2000 Monthly Normals

(2) Derived from station's available digital record: 1932-200

(3) Derived from 1971-2000 serially complete daily data a surficial glacial drift aquifer averaging 150 feet in thickness and is comprised of silt interbedded with clay and sand overlaid by sand and finally by a thin layer of wind-blown sand (Winter et al 1984; Baker and Paulson 1967). The water table varies between five and 10 feet below the surface and is highest in the spring when spring snow melt and precipitation infiltrates soils; water tables generally slope east and north toward the Sheyenne Valley. The Sheyenne Delta Aquifer may store up to 4 million acre-feet with 50,000 acre-feet of recharge annually. Recharge occurs from precipitation and matches discharge occurring through wells, springs, and evapotranspiration (Baker and Paulson 1967). The Hankinson

Table 2. Precipitation data from 1971-2000 at Lisbon, North Dakota (from National Climatic Data Center, www.ncdc.noaa.gov).

Precipitation (inches)																								
	Precipitation Totals									Mean Number of Days (3)				Precipitation Probabilities (1) Probability that the monthly/annual precipitation will be equal to or less than the indicated amount										
	Means/ Medians(1)		Extremes							Daily Precipitation				Monthly/Annual Precipitation vs Probability Levels. These values were determined from the incomplete gamma distribution										
Month	Mean	Med-ian	Highest Daily(2)	Year	Day	Highest Monthly(1)	Year	Lowest Monthly(1)	Year	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
Jan	.63	.54	.70	1996	18	1.71	1994	.02	1990	5.3	2.1	.2	.0	.06	.11	.20	.29	.38	.49	.61	.77	.99	1.34	1.69
Feb	.48	.39	1.16	1958	27	1.78	1979	.02	1983	4.0	1.8	.2	.0	.04	.08	.14	.21	.28	.37	.47	.59	.76	1.04	1.32
Mar	1.09	.99	1.32	1996	24	3.10	1977	.19	1997	5.4	3.4	.7	.1	.24	.34	.49	.64	.78	.94	1.11	1.32	1.60	2.03	2.45
Apr	1.47	1.18	1.69	1935	25	6.64	1986	.00	1988	6.9	3.9	1.0	.2	.08	.21	.44	.66	.89	1.14	1.44	1.82	2.32	3.16	3.97
May	2.59	2.39	2.46	1970	29	6.78	1972	.17	1976	9.0	5.4	1.9	.4	.71	.96	1.33	1.65	1.97	2.31	2.68	3.12	3.69	4.58	5.42
Jun	3.45	2.95	4.31	1975	29	16.14	1975	.48	1987	9.4	5.9	2.0	.8	.54	.84	1.34	1.81	2.30	2.84	3.46	4.21	5.22	6.86	8.43
Jul	2.87	2.75	3.01	1948	21	8.53	1995	.36	1976	8.8	5.4	1.7	.6	.59	.86	1.28	1.66	2.05	2.46	2.93	3.49	4.23	5.41	6.54
Aug	2.27	1.86	4.37	1941	10	5.26	1972	.61	1984	7.5	4.4	1.4	.5	.71	.93	1.25	1.53	1.79	2.07	2.37	2.72	3.18	3.89	4.55
Sep	2.20	1.74	6.00	1978	12	6.77	1978	.18	1974	7.1	4.0	1.0	.5	.25	.42	.72	1.03	1.36	1.73	2.15	2.69	3.41	4.61	5.77
Oct	1.82	1.33	2.97	1961	11	6.84	1998	.08	1991	6.0	3.5	1.2	.4	.11	.21	.43	.68	.96	1.29	1.69	2.20	2.92	4.14	5.35
Nov	.86	.66	1.60	1977	20	3.49	1977	.00	1999	4.9	2.4	.3	.1	.03	.09	.20	.33	.46	.62	.81	1.05	1.37	1.93	2.48
Dec	.45	.32	.75	1975	13	1.68	1972	.00	1986	4.7	1.6	@	.0	.02	.05	.11	.18	.25	.33	.43	.55	.71	.99	1.26
Ann	20.18	19.62	6.00	Sep 1978	12	16.14	Jun 1975	.00+	Nov 1999	79.0	43.8	11.6	3.6	12.67	14.06	15.87	17.27	18.53	19.76	21.05	22.48	24.24	26.83	29.10

+ Also occurred on an earlier date(s)
# Denotes amounts of a trace
@ Denotes mean number of days greater than 0 but less than .05

(1) From the 1971-2000 Monthly Normals
(2) Derived from station's available digital record: 1932-2001
(3) Derived from 1971-2000 serially complete daily data

Means/Medians (1)					Extremes (2)										Snow Fall >= Thresholds					Snow Depth >= Thresholds			
Month	Snow Fall Mean	Snow Fall Median	Snow Depth Mean	Snow Depth Median	Highest Daily Snow Fall	Year	Day	Highest Monthly Snow Fall	Year	Highest Daily Snow Depth	Year	Day	Highest Monthly Mean Snow Depth	Year	0.1	1.0	3.0	5.0	10.0	1	3	5	10
Jan	10.6	10.2	7	6	8.0	1996	18	18.3+	1996	24	1994	17	20	1994	4.2	3.0	1.1	.3	.0	24.4	22.9	17.4	10.1
Feb	5.1	4.0	8	8	7.0	1971	4	15.0	1979	21	1982	7	18	1986	2.8	2.0	.7	.1	.0	21.7	19.5	11.3	7.4
Mar	6.6	6.9	3	1	9.0	1982	20	17.1	1996	17	1989	9	10	1989	2.5	1.7	.9	.2	.0	10.0	8.0	5.2	1.3
Apr	1.3	.1	#	0	5.0	1992	10	7.0	1992	5	1992	10	1	1992	.6	.5	.1	@	.0	.8	.2	.1	.0
May	.1	.0	0	0	3.0	1976	2	3.0	1976	0	0	0	0	0	@	@	@	.0	.0	.0	.0	.0	.0
Jun	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jul	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Aug	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sep	#	.0	0	0	#	1985	25	#	1985	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Oct	.4	.0	#	0	3.0	1972	30	4.5	1992	3+	1992	16	#+	1995	.2	.1	.1	.0	.0	.2	.1	.0	.0
Nov	7.9	6.9	1	#	16.0	1977	20	30.6	1993	23	1993	27	7	1996	3.4	2.2	1.3	.4	@	9.4	4.9	2.1	.8
Dec	5.7	3.5	4	2	8.0	1972	30	20.7	1972	26	1996	23	17	1996	4.2	2.5	.4	.1	.0	18.6	11.5	7.4	2.6
Ann	37.7	31.6	N/A	N/A	16.0	Nov 1977	20	30.6	Nov 1993	26	Dec 1996	23	20	Jan 1994	17.9	12.0	4.6	1.1	@	85.1	67.1	43.5	22.2

+ Also occurred on an earlier date(s) #Denotes trace amounts
@ Denotes mean number of days greater than 0 but less than .05
-9/-9.9 represents missing values
Annual statistics for Mean/Median snow depths are not appropriate

(1) Derived from Snow Climatology and 1971-2000 daily data
(2) Derived from 1971-2000 daily data
Complete documentation available from:
www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

Aquifer, also a surficial drift aquifer, is composed of beach deposits separated from the Sheyenne Delta Aquifer by till and lake clay in Richland County. Aquifers may be more than 100 feet in thickness becoming thinner to the south and east; the groundwater table lies within approximately 10 feet of the surface. Recharge occurs from precipitation with little subsurface connectivity with other areas (Baker and Paulson 1967).

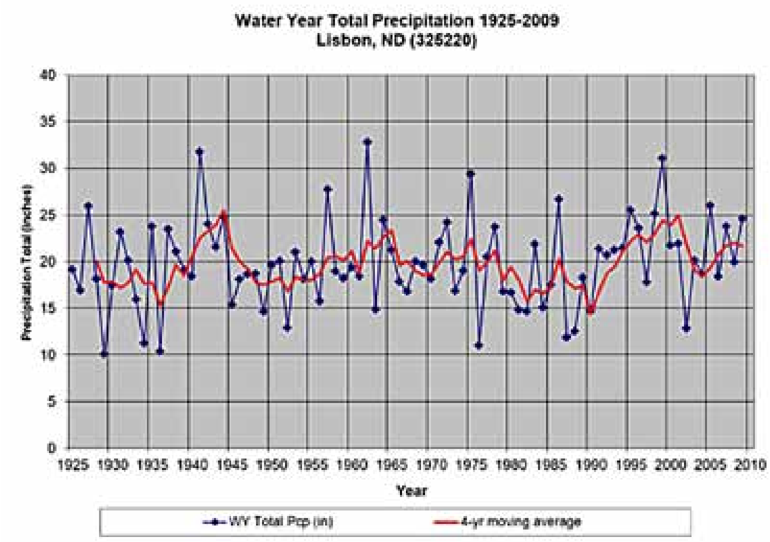


Figure 12. Total water year precipitation (inches) at Lisbon, North Dakota, 1925-2009 (from Striffler 2013).

PLANT AND ANIMAL COMMUNITIES

The RRV and adjacent glaciated Drift Plain lie within the Cold Temperate Grasslands Biotic Region, and includes tallgrass prairie in the eastern Lake Agassiz Plain that trends toward mixed-grass prairie in the western Drift Plain (Fig. 18; Brown et al. 2007;

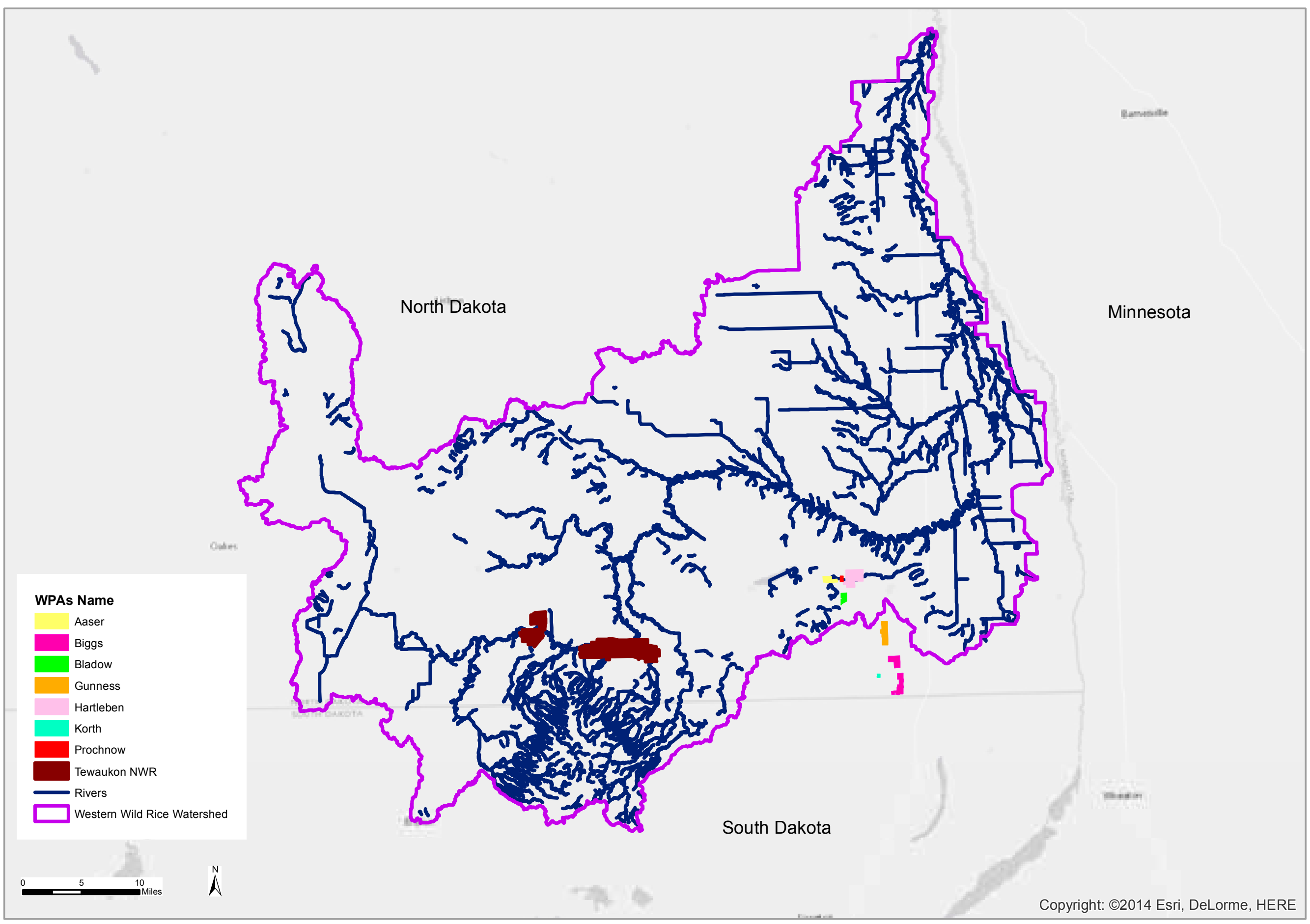


Figure 13. Location of the Wild Rice River watershed.

Heidel 1986). Prairie areas are imbedded with numerous moraine wetland depressions – the prairie potholes. Tallgrass and mixed-grass prairie communities are not separated by sharp boundaries, but gradually transition from tallgrass to mixed-grass in western parts of the Tewaukon NWR Complex. Mesic-type tallgrass and mixed-grass communities tend to occur on higher elevation drier hill tops and slope topography, while wet-mesic and wet prairie/meadow communities occur on lower hill slopes and moraine valley areas. Consequently, mesic tallgrass prairie occurs on hill slope sites and in the eastern areas of the Tewaukon WMD, while mesic mixed-grass prairie assemblages tend to occur on higher elevation drier sites mostly in western areas of Tewaukon and Sprague NWR units. Sites with as little as 10 feet difference in elevation can have different prairie species assemblages and have different soil types (USFWS 2000:26).

The Tewaukon NWR Complex contains numerous "kettle-type" pothole wetland depressions ranging from small temporarily flooded sites with wet prairie/meadow assemblages to larger basins with semipermanent water regimes that support persistent emergent (PEM)-open water-submergent aquatic vegetation (SAV). Pothole basins and low elevation wet prairie/meadow habitats are interspersed within the rolling prairie landscape. Several large relict glacial lakes also are present on and adjacent to the Tewaukon NWR Complex lands. These include the namesake Tewaukon and Sprague lakes among others.

Tallgrass prairie was the dominant vegetation type across the eastern portion of the Great Plains during the Presettlement period (Fig. 19, Steinauer and Collins 1996). Historically, tallgrass prairie covered approximately 75% or 13,000 km² of the RRV (Heidel 1986). General Land Office Surveys (GLO) conducted in the 1800s for Richland County indicated that five different vegetation communities existed: tallgrass prairie, shrub thicket, lowland marsh, forest, and savanna. GLO summaries indicate that of the trees present, American elm (*Ulmus americana*) was most prevalent along the

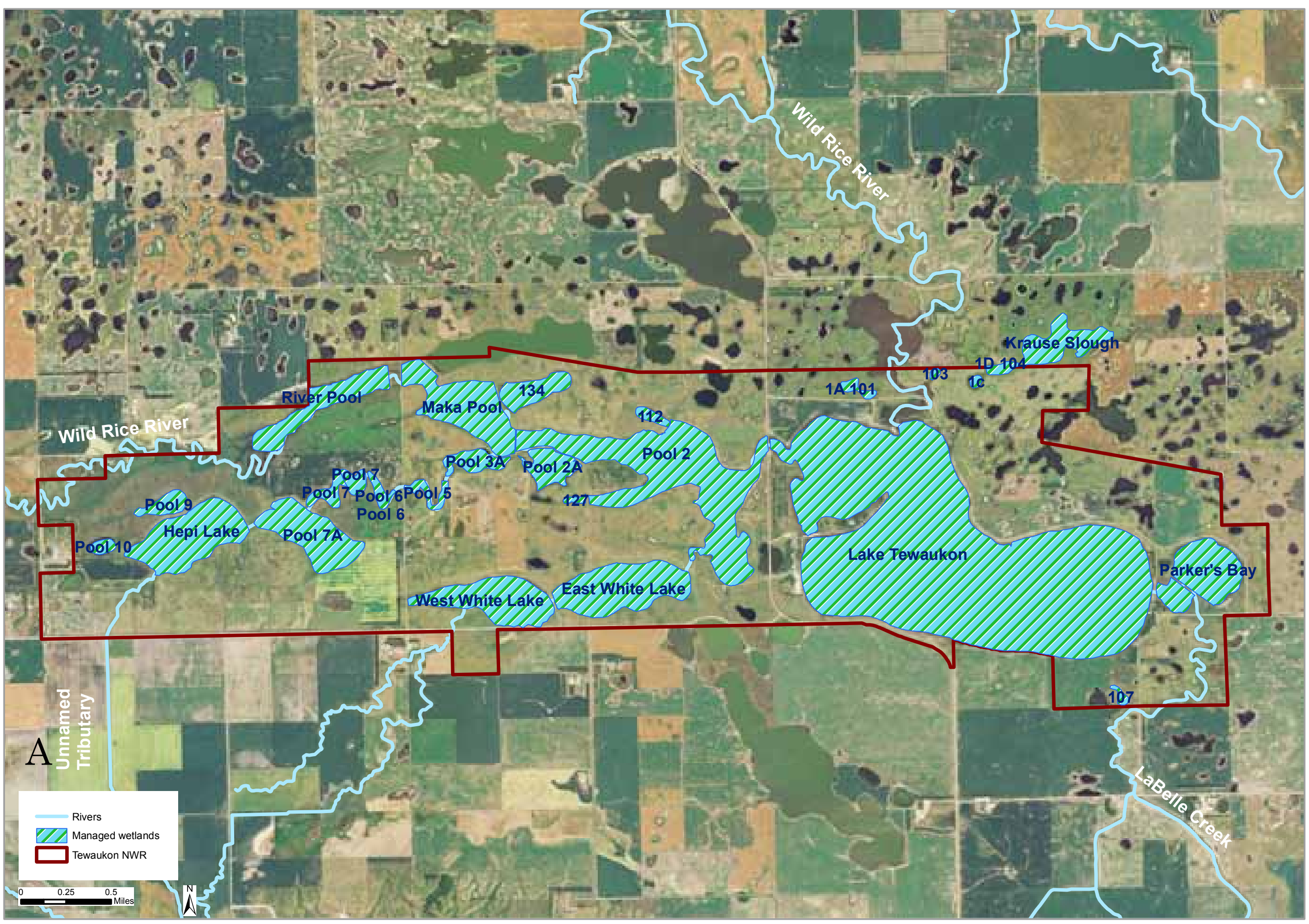


Figure 14. Rivers, creeks, tributaries, and major wetland/lake areas on a) Tewaukon, and b) Sprague Lake (data from USFWS).

Wild Rice River with bur oak (*Quercus macrocarpo*) associated commonly with savanna habitats (Table 3; Gantt 1980). Early-1900s soil surveys describe the region as having little to no trees except a few along the Wild Rice River, Red River, and Lake Tewaukon, although limited number of trees may have been due to early settlers using trees for building and heat (Hutton et al. 1920; Bennett et al. 1908).

Prairie Communities

Native prairie community classification, ranging from low wet elevations to higher drier hilltops and slopes, at the Tewaukon NWR Complex includes the following types based on a refinement of Heidel's (1986) botanical classification for North Dakota (USFWS 2000):

Wet Prairie/Meadow

This community is found in temporary wetland basins, low inter-moraine hill drainage areas, and in bands around some larger deeper semipermanently flooded wetlands. Some botanical sources refer to this community type as wet meadow (Smeins 1967). Vegetation is dominated by more water tolerant prairie grasses such as prairie cordgrass (*Spartina pectinata)*, switchgrass (*Panicum virgatum*), and northern reedgrass (*Calamagrostis stricta*); forbs such as Maximillian sunflower (*Helianthus maximilianii*) and prairie dogbane (*Apocynum cannabinum*); and wetland herbaceous and sedge/rush species.

Wet-Mesic Tallgrass Prairie

This community is found on wetter lower moraine hill slopes with moderately well-drained soils and is a transitional community between the lower elevation inter-hill valley wet prairie/meadow and higher elevation drier hillslope and hill top mesic tallgrass or mixed-grass sites. Wet-mesic prairie areas are dominated by tall warm-season grasses and showy forbs including switchgrass, big bluestem

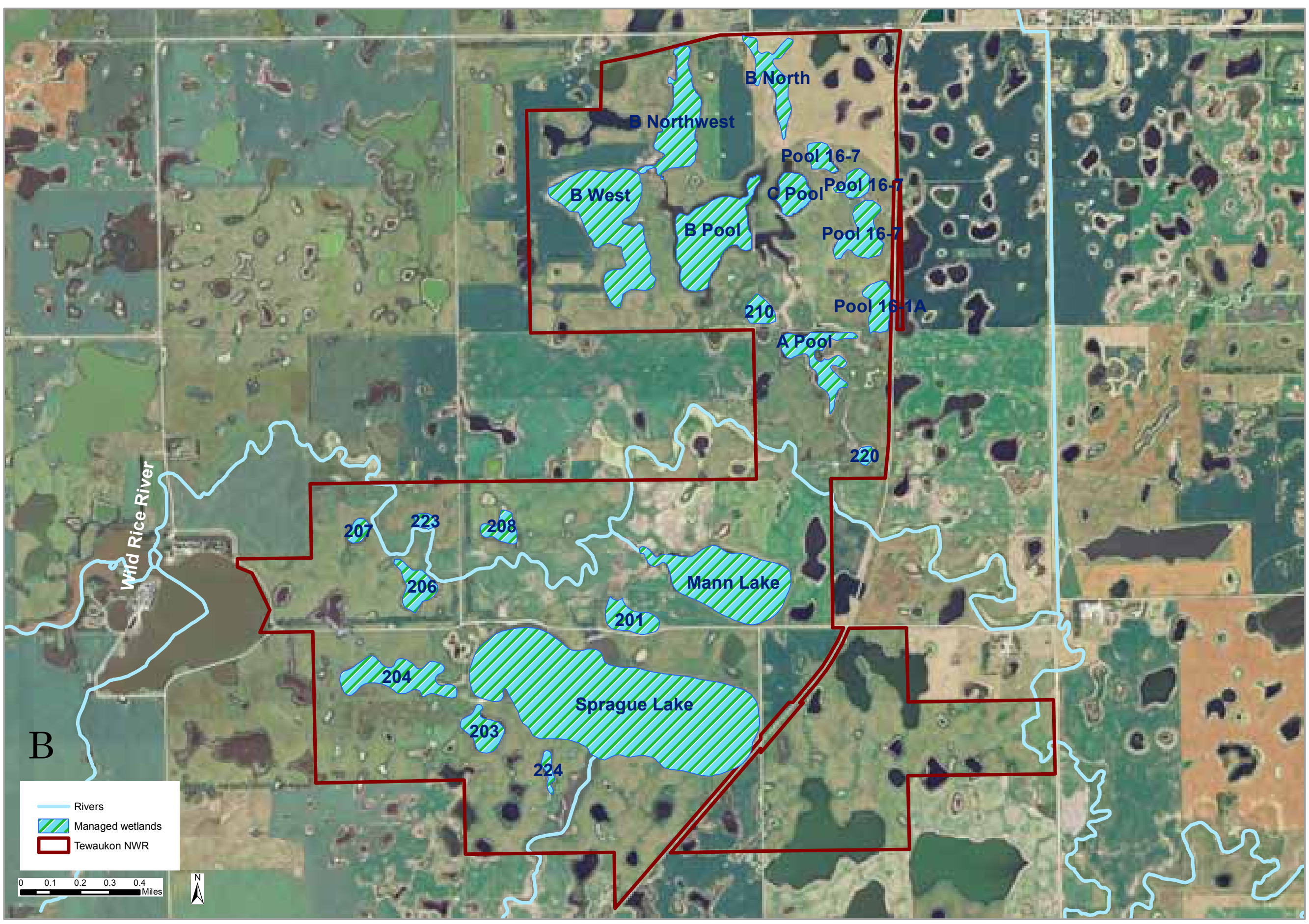


Figure 14, continued. Rivers, creeks, tributaries, and major wetland/lake areas on a) Tewaukon, and b) Sprague Lake (data from USFWS).

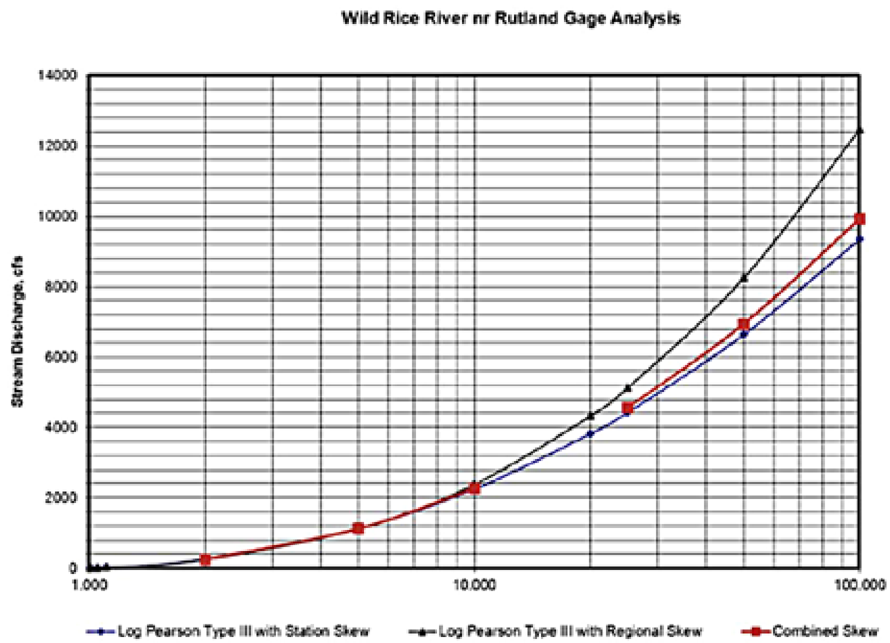


Figure 15. Stage-discharge relationship curve for the Wild Rice River at Rutland, North Dakota (from Striffler 2013).

(*Agropyron gerardii*), northern reedgrass, Baltic rush (*Juncus balticus*), Indian grass (*Sorghastrum nutans*), tall blazing star (*Liatris pycnostachya*), wild lily (*Lilium philadelphicum*), white camas (*Zigadenus elegans*), Maximillian sunflower, Canada anemone (*Anemone Canadensis*), and black-eyed susan (*Rudbeckia hirta*). Areas with sandy soils have more extreme soil moisture dynamics and usually have fewer forbs than non-sandy soil areas.

Central Mesic Tallgrass Prairie

This community is found on level to rolling glacial till plains and lower river valley slopes. It contains tall grasses such as big bluestem and Indian grass and mid-height grasses such as porcupine grass (*Stipa spartea*) and little bluestem (*Andropogon scoparius*). Other grasses include green needlegrass (*Stipa viridula*), and sideoats grama (*Bouteloua curtipendula*). Forbs in this community are diverse and may be locally abundant including narrow-leaved blazing star (*Liatris pundata*), leadplant (*Amorpha canescens*), stiff goldenrod (*Solidago rigida*), hoary puccoon (*Lithospermum canescens*), showy milkweed (*Asclepias speciosa*), white prairie clover (*Dalea candida*), and stiff sunflower (*Helianthus rigidus*). Mesic tallgrass areas with sandy soils usually have abundant prairie sandreed (*Calamovilfa longifolia*) present.

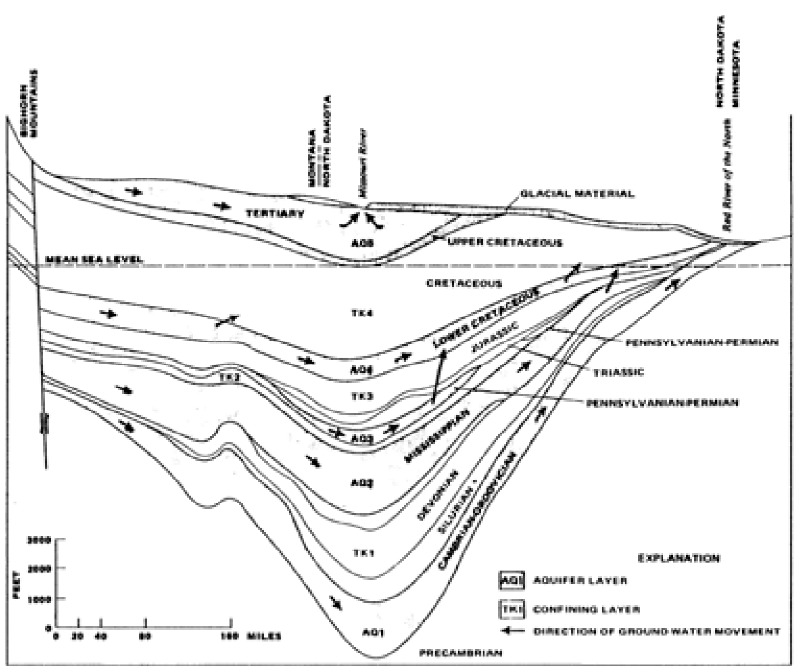


Figure 16. Generalized geohydrologic section showing bedrock aquifers and direction of groundwater flow – lines of sections begin at the Bighorn Mountains in Montana and continue across eastern Montana and North Dakota (from Winter et al. 1984).

Dry-Mesic Tallgrass Prairie

This community is found on dry hill tops and slopes of eastern areas of the Tewaukon WMD. Heidel (1986) also recognizes a "till" subtype of this community in western Drift Plain areas of moraine side slopes along river valleys. Soils in mesic tallgrass prairie areas are well-drained to excessively drained. The community is dominated by mid-height grasses including little bluestem,

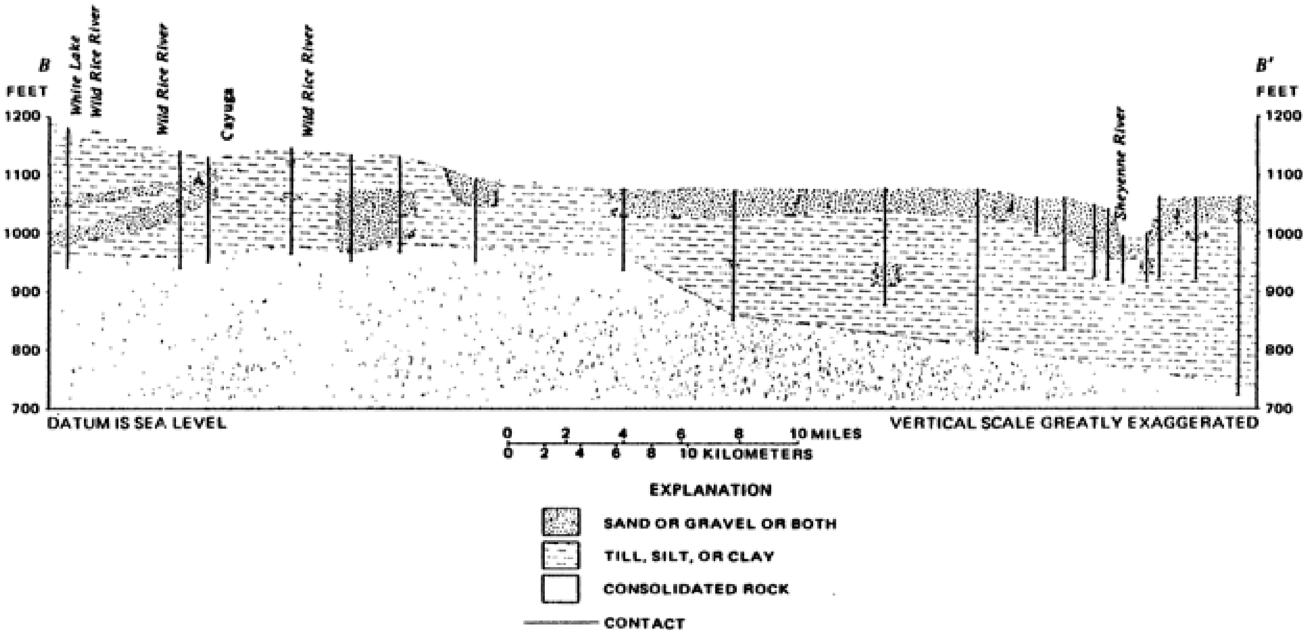


Figure 17. Cross-section of the Spiritwood and Sheyenne aquifers in southeast North Dakota (from Winter et al. 1984).

porcupine grass, June grass (*Koeleria pyramidata*), sideoats grama, and Indian grass. Prairie sandreed is common and sand bluestem (*Andropogon hallii*) is occasionally present on sandy soil areas. Common forbs include narrow-leaved blazing star, yellow coneflower (*Ratibidia columnifera*), stiff sunflower, alum root (*Heuchera richardsonii*), purple coneflower (*Echinacea angustifolia*), thimbleweed (*Anemone cylindrical*), prairie smoke (*Geum triflorum*), and pasture sage (*Artemisia ludoviciana*). Sub-shrubs may be common in some areas and include leadplant, prairie wild rose (*Rosa arkansana*), and buckbrush (*Sympharicaros occidentalis*).

Mesic Mixed-grass Prairie

This community occurs on highly drained and dry glacial till of hillsides, slopes and river valleys in western parts of the Tewaukon NWR Complex, including higher elevations on the Tewaukon and Sprague Lake Units. Common grasses include green needlegrass, bearded wheatgrass (*Agropyron subscundum*), western wheatgrass (*Agropyron smithii*), and porcupine grass. Common forbs are similar to those in dry-mesic tallgrass prairie communities and include purple coneflower, alum root, stiff sunflower,

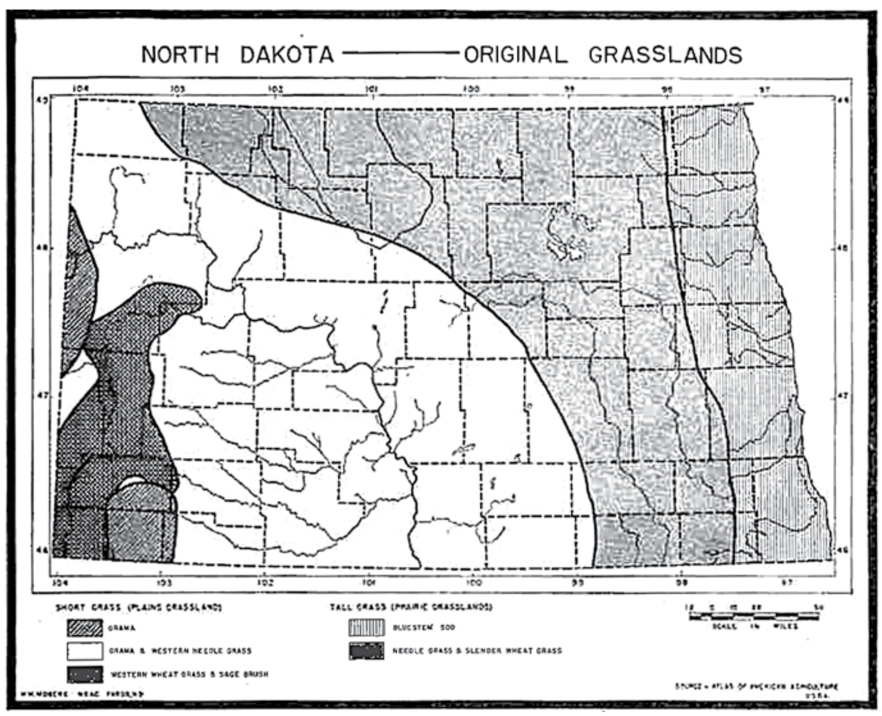


Figure 18. Historical location of the tallgrass and mixed-grass prairies in North Dakota (from Moberg 1952).

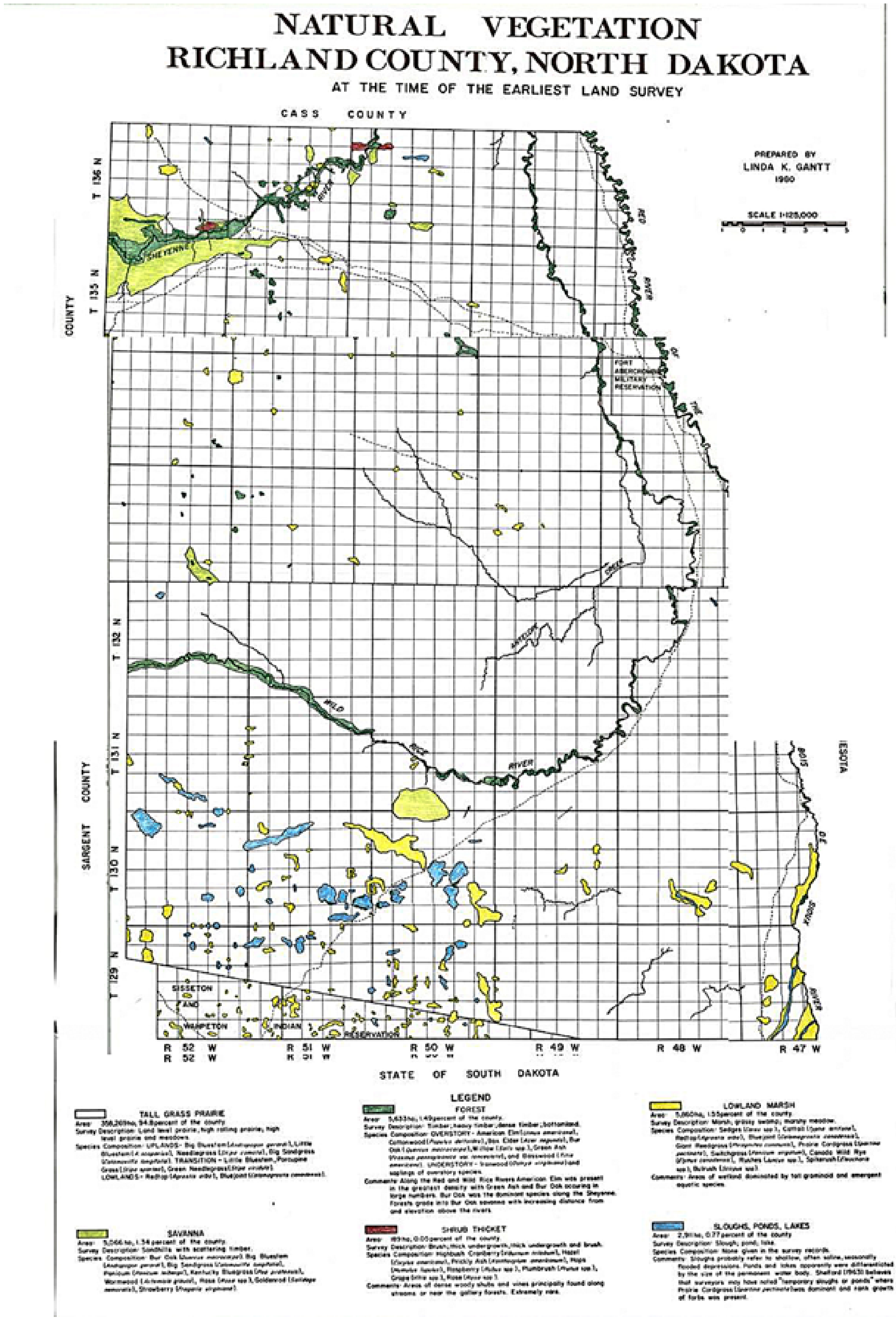


Figure 19. Presettlement vegetation communities in Richland County, North Dakota taken from General Land Office surveys (from Gantt 1980).

Table 3. GLO density and dominance values of tree species located along the Red and Bois de Sioux Rivers (from Gantt 1980).

Species	No. of trees	Basal Area (Sq. in.)	Rel. Density (%)	Rel. Dominance (%)
Salix spp.	10	778.36	9.61	5.46
Quercus velutina	1	63.62	0.96	0.45
Acer negundo	16	1207.96	15.38	8.49
Ulmus americana	34	7933.25	32.69	55.81
Quercus alba	4	141.38	3.85	0.99
Fraxinus americana	10	695.90	9.61	4.90
Fraxinus pennsylvanica	10	885.89	9.61	6.23
Quercus macrocarpa	17	2176.32	16.35	15.31
Tilia americana	1	254.50	0.96	1.79
Populus deltoides	1	78.54	0.96	0.55
Totals	104	14215.72	99.98	99.98

narrow-leaved blazing star, and yellow coneflower (*Ratibidia columnifera*). Shrubs include leadplant, prairie wild rose and buckbrush.

The tallgrass and mixed-grass prairie ecosystem in the Tewaukon NWR region historically was maintained by frequent disturbances, especially wildfire and herbivory by native ungulates and rodents. It has been estimated that these prairies burned frequently (Axelrod 1985, Bragg 1982, Bragg and Hulbert 1976, Hulbert 1986). Lightning strikes were likely the most common cause of fires and would have typically occurred in mid to late summer (Bragg 1982). Native people also may have intentionally or accidentally started some fires (Pyne 1994). Herbivory by native ungulates including bison (*Bison bison*), elk (*Cervus canadensis*), and mule deer (*Odocoileus hemionus*) was important along with herbivory by abundant small mammals such as pocket gophers (*Geomys bursarius*), ground squirrels, and mice and voles (Bailey 1926). Some insects such as ants and grasshoppers likely consumed prairie plants sometimes in abundance. Other important disturbance events included the periodic extended drought, hail, tornados and wind storms and periodic flooding in low areas along the Wild Rice River and other local streams. Collectively, these disturbance processes shaped the prairies into complex and diverse floral assemblages.

Wetland Communities

Wetlands in the Tewaukon NWR region are mainly “kettle” or “pothole” basins with variable flooding regimes. Early explorers and travelers into the region described the extensive interspersion of pothole wetlands within the “sea of prairie grasses” (Hutton et al. 1920, USFWS 2000). The density of pothole depressions may have exceeded 120 to 160 basins/square mile in some parts of the RRV. Wetland basins at the Tewaukon Complex NWR range from small temporary and seasonally flooded types to the larger semipermanently or permanently flooding types. These diverse wetland basins have typical zones of vegetation species related to water depth, permanence, and configuration of the basin/depression (Fig. 20). Specific types of wetlands in the Tewaukon NWR region (Fig. 20, Stewart and Kantrud 1971, Cowardin et al. 1979, Kantrud et al. 1989) included:

Temporary Wetlands (Type II)

These shallow temporary wetland depressions typically receive inputs of surface water in spring following local snowmelt and runoff, usually in late May to early June. Type II wetlands typically are “recharge” basins where at least some of the water running into the basin subsequently infiltrates or “recharges” the underlying soil strata (Winter 1989). Many temporary wetlands occur in Tonka soils. These depressions hold water for only short periods (1-3 weeks) and frequently reflood for short periods after heavy summer and fall rains. Common plant species in temporary wetlands include those found in wet prairie/meadow communities described above, along with smartweeds (*Polygonum* spp.), rushes (*Juncus* spp.), spikerush (*Eleocharis* spp.), and sedges (*Carex and Cyperus* spp.).

Seasonal Wetlands (Type III)

Seasonal wetland habitats are present in pothole depressions that hold water from spring

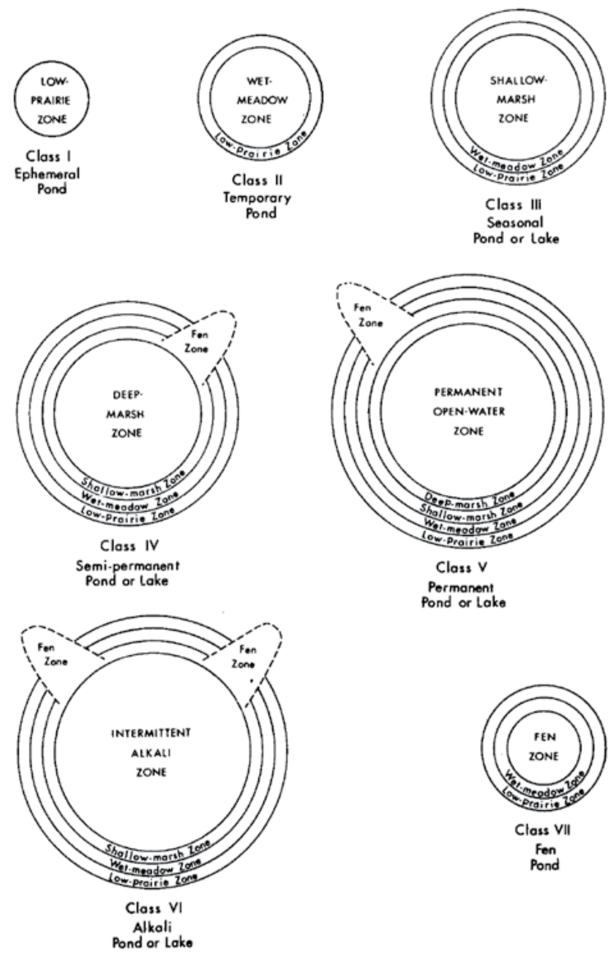


Figure 20. Typical vegetation zonation patterns in different types of northern prairie wetlands (from Stewart and Kantrud 1971).

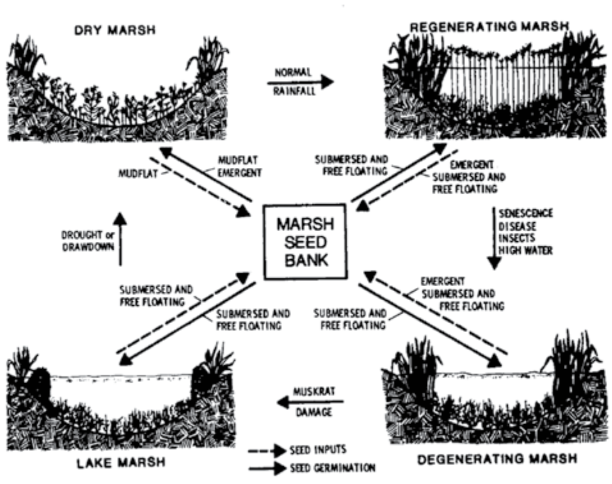


Figure 21. Generalized vegetation cycle in northern prairie wetlands from wet to dry periods (from Van der Valk and Davis 1978).

snowmelt and surface water runoff until mid July to early August. Type III wetlands can be either "recharge" or "discharge" basins. The latter occurs when groundwater in upper slopes actually "discharges" into the basin from ground seepage (Winter 1989). Many Type III basins occur in Parnell soil areas. These basins also commonly reflood after local rain events and are characterized by smartweeds, rushes, sedges, and some PEM species including small areas of cattail (*Typha* spp.).

Semipermanent Wetlands (Type IV)

Large, deeper pothole depressions typically receive and hold surface water in years with average or above precipitation from spring throughout summer (3-5 months). Semipermanent wetlands may remain dry, or be shallowly flooded in the deepest areas for short periods, in years with below average precipitation. Semipermanent wetlands have scattered areas of open water with SAV surrounded by PEM such as cattail and hardstem (*Scirpus acutus*) or softstem bulrush (*Scirpus taber naemontani*).

Permanent Wetland/Lakes (Type V)

The largest and deepest depressions in the Tewaukon NWR Complex include scattered relict glacial lakes (such as Tewaukon, Sprague and Hepi lakes) that hold at least some water year round, except historically in successive years of below average precipitation. These lake-type wetlands have well-defined zones of vegetation ranging from open water/SAV in deeper areas to borders of PEM and some wet prairie/meadow or seasonal herbaceous species on fringe areas. The shallow emergent zone of potholes and relict lakes/sloughs commonly is occupied by broad-leaved cattail (*Typha latifolia*), narrow-leaved cattail (*Typha angustifolia*), hardstem bulrush, three-square bulrush (*Schoenoplectus pungens*), common reed (*Phragmites communis*), and bur-reed (*Sparganium eurycarpum*) (Smeins 1967, Pemble 1995). Plants in the shallow emergent zone are taller and coarser than in seasonal wet meadow zones. Deeper semipermanently flooded PEM zones are dominated by several species of bulrush, cattail, and common reed along with coontail (*Ceratophyllum demersum*) and bladderwort (*Utricularia vulgaris*). In the deepest open water areas many SAV plants are present including pondweeds (*Potamogeton* sp.), coontail, water starwort (*Cal-*

Table 4. Stages of typical habitat/vegetation cycles in northern prairie wetlands (from Kantrud et al. 1989).

Stage name	Water in relation to basin capacity	Vegetation	Muskrat populations	Bird populations	Conspicuous indicator conditions
Dry marsh	Absent or low; emergents dry or nearly dry at base	Dense revegetation; most species find a suitable seedbed	Low to absent; populations centrally located	Redwings sparse; some use by upland birds	Redwings; few muskrat lodges; low water
Dense marsh; more vegetation than open water	Increasing water levels; emergents flooded	Very dense; rate of opening dependent upon muskrat populations and influence of flooding on certain species	Increasing	Numbers and variety increasing	Redwings increase; first yellowheads adjacent to sparse open pools; few coots and grebes
Hemi-marsh; open water and vegetation are equal	Median to near maximum	Muskrat eat-out; flotation and death; decline in shallow-water species. Veg. propag. by deep-water species	Increasing rapidly; well distributed	Maximum species diversity and production for most species	Many redwings; yellowheads uniformly distributed; coots and pied-billed grebes abundant
Open marsh; more open water than vegetation	Maximum	Submergents and deep-water species persist; others gone or going	Maximum or declining	Most species declining; a few swimming species tolerate as long as some vegetation persists	Sparse bird populations and emergents
Open water marsh (virtually an eutrophic lake)	Maximum or as low as median	Hardstem bulrush may persist in sparse populations	Sparse; bank dense common	Redwings use shoreline vegetation; other species virtually absent except as migrants	Redwings use shoreline shrubs and trees

litriche sp.), and white water crowfoot (*Ranunculus aquatilis*).

Wetlands at the Tewaukon NWR Complex historically were driven primarily by seasonally and annually dynamic inputs of freshwater from the upland watershed and some discharge from groundwater (Winter 1989). Given the interannual dynamics of regional precipitation and flooding (at about 20-30-year alternating wet-dry cycle – see earlier section on regional climate and hydrology), the types and extent of wetland vegetation likely varied among years (Fig. 21 ,Table 4).

Historical Distribution of Vegetation Communities

A HGM matrix of potential historic communities present on the Tewaukon NWR Complex areas evaluated in this study was prepared based on the combination of geomorphology, soils, topography, and hydrology (Table 5). This matrix of understanding about communities was then used to map the historical distribution of major vegetation communities at Tewaukon NWR and the Hartleben WPAs (Fig. 22). This HGM map indicates a diverse landscape of vegetation communities was present including: 1) mesic tallgrass and/or mesic mixed-grass prairie on moraine hill tops and upper slopes, 2) wet-mesic tallgrass prairie on lower hill slopes and river valley slopes, 3) wet prairie/meadow communities in inter-hill drainages and margin-edges of potholes and relict lake basins, 4) small pothole wetland depressions in moraines with seasonal to semipermanent water regimes and associated zones of seasonal herbaceous to PEM stands, 5) narrow bands of riparian woodland along parts of the Wild Rice River and Tewaukon Lake, and 6) larger relict glacial lakes and sloughs that contain open water-SAV-PEM communities. For purposes of HGM mapping, mesic and wet-mesic prairie was also separated into loamy vs. sandy soil types that support slightly different species assemblages. Relict lake boundaries included large depressions from the deepest centers of the depressions to high water edges where inundation was irregular and dynamic among wet vs. dry years.

Key Animal Species

Animal communities historically present on the Tewaukon NWR Complex were dominated by species adapted to prairie grasslands, potholes, and floodplain conditions (USFWS 2000, see also van der Valk 1989). These species included numerous grassland birds, waterbirds, mammals, and amphibian/reptiles. Precipitation cycles and flash floods in the RRV and Drift plain caused the availability of wetland habitat to be highly variable among years. Most waterbirds and waterfowl probably

Table 5. Hydrogeomorphic (HGM) matrix of historic distribution of vegetation communities/habitat types on the Tewaukon National Wildlife Refuge Complex. Relationships were determined from old aerial photographs, plat and GLO maps (Fig. Fig. 17) geomorphology maps (Fig. 4-6), soil maps (Fig. 7) LiDAR topographic maps (Fig. 8), various historical accounts of the region (e.g., Hutton et al. 1920, Bailey 1926, Steinauer and Collins 1996), botanical relationships (Moberg 1952, Bailey 1995, Kantrud et a. 1989, Axelrod 1985, Bragg 1982, Bragg and Hulbert 1976, Heidel 1986), and land cover maps prepared by the U.S. Fish and Wildlife Service (Fig. 21).

Habitat type	Geomorphic surface	Soil type	Flood frequency
Mesic prairie[a]	Moraine hill tops and high slopes	loam and sandy loam	On-site precipitation
Wet-mesic prairie[a]	Lower moraine slopes, higher drainage edges	loam, sandy loam, silt loam	On-site precipitation and surface/ground water discharge
Wet prairie/meadow	Moraine drainages and high edges of wetlands and lakes	silt loam and silty clay loam	Seasonal
Riparian woodland	Edges of Wild Rice River and Lake Tewaukon	Lamoure loams	Annual, overbank and saturated river edges
Pothole depression	moraine and relict lacustrine depressions	silty clay, silt clay loam	Seasonal to semi-permanent
Glacial lakes	Relict larger and deeper depressions in moraine, lacustrine, and creek floodplain areas	silty clay, silt clay loam	Semi-permanent to permanent

[a] Mesic and wet-mesic prairie can be separated into sandy and nonsandy types based on soil type.

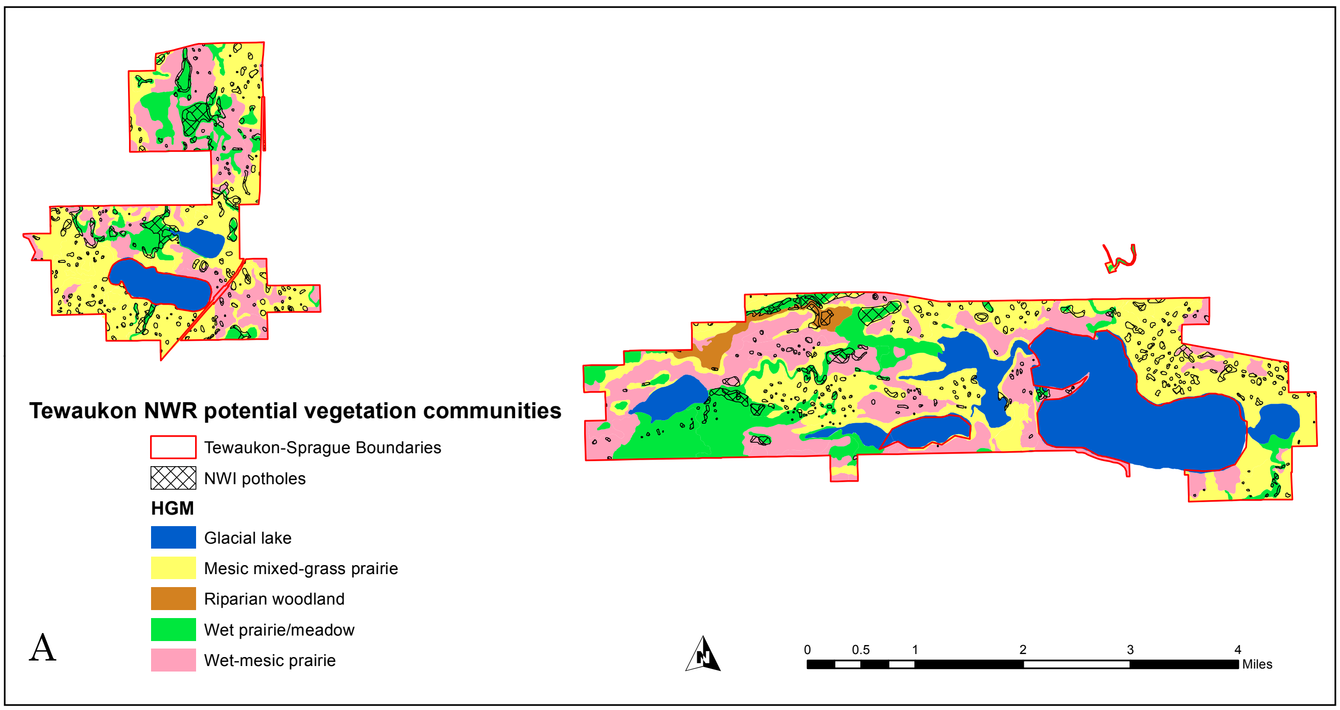
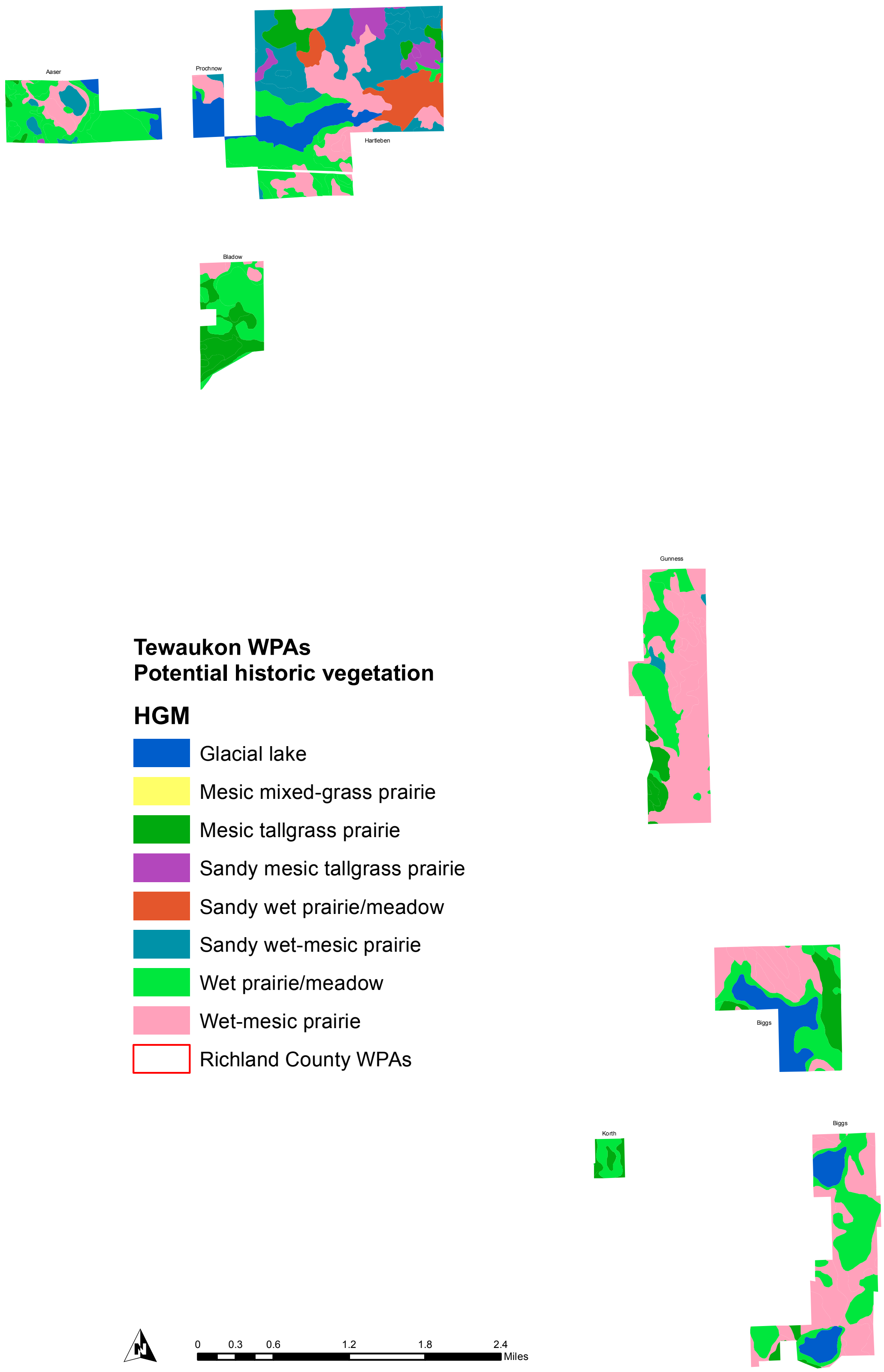


Figure 22. Potential natural vegetation communities at: a) Sprague Lake and Tewaukon National Wildlife Refuge units; b) Hartleben, Aaser, Prochnow, and Bladow WPAs; and c) Biggs, Gunness, and Korth WPAs (see Table 5 for information on community attributes and mapping criteria).



B

Figure 22, continued. Potential natural vegetation communities at: a) Sprague Lake and Tewaukon National Wildlife Refuge units; b) Hartleben, Aaser, Prochnow, and Bladow WPAs; and c) Biggs, Gunness, and Korth WPAs (see Table 5 for information on community attributes and mapping criteria).

used the historic wetlands present on Tewaukon NWR and WPAs during the migration, nesting, and brood-rearing periods; these included Canada goose (*Branta canadensis*), snow goose (*Anser caerulescens*), mallard (*Anas platyrhynchos*), blue-winged teal (*Anas discors*), green-winged teal (*Anas crecca*), northern pintail (*Anas acuta*), and American coot (*Fulica americana*), based on Thomas S. Roberts visit in 1883 (Krapu 1996). Grassland bird species such as sharp-tailed grouse (*Tympanuchus phasianellus*), greater prairie chicken (*Tympanuchus cupido*), and savannah sparrows (*Passerculus sandwichensis*) may have been present depending on climatic conditions. Mammals such as bison, mule deer, grizzly bear (*Ursus horribilis*), otter (*Lutra* spp.), beaver (*Castor canadensis*), and red fox (*Vulpes vulpes*) were prevalent, among others (Lounsbury 1919). Amphibians and reptiles such as the western hognose snake (*Heterdon nasicus*), northern prairie skink (*Eumeces septentrionalis*), great plains toad (*Bufo cognatus*), and Canadian toad (*Bufo hemiophrys*) were in various vegetation communities (Hoberg and Gause 1992). A complete list of current and historical animal species documented to occur on the Tewaukon NWR Complex is provided in the refuge CCP (USFWS 2000).

Jack Lalor, refuge staff

CHANGES TO THE TEWAUKON ECOSYSTEM

SETTLEMENT AND EARLY LAND USE

The Northern Great Plains, including the Tewaukon NWR Complex region, was first populated by Paleo-Indians migrating across the Bering Straits around 20,000 years before the present (BP) (Fitting 1970, Key 1982). The Paleo-Indians continued to inhabit the region as portions of the area transitioned from spruce-dominated parkland to deciduous parkland at the end of the Pleistocene (Yansa 2007). The Paleo-Indians were migratory, and they actively hunted big game along with gathering local plants. From about 6,000 BP to the early 1800s the Plains Archaic populations occupied the Tewaukon NWR Complex region and they were hunter-gatherers that utilized small arrow points associated with the atlatl. The use of smaller points coincided with a shift from hunting mammoth and mastodons like their ancestors to hunting bison, elk, and deer (Key 1982). The Plains Woodland period began much later than Woodland periods to the east and is characterized by the introduction of pottery. The RRV and adjacent Drift Plain lie within the Northeastern Periphery as designated by Wedel (1961) to describe use of the Great Plains by the Woodland peoples. Early sites are located along rivers and streams occurring from 400 to 50 BP. The Middle Woodland period incorporated mound burial and increasing population densities. It wasn't until the Early Late Woodland period from 300 to 700 AD that horticulture became evident in the PPR, although hunting and gathering were still the dominant way of life. The bow and arrow were utilized at this time with horticulture increasing into the Late Woodland period from 700 to 900 AD (Key 1982). Several studies have indicated that pre-historic and historic human populations numbered approximately 100,000 throughout the Great Plains, primarily dependent upon an estimated 30 million bison (Steckel and Prince 2001; Epp and Dyck 2002). One study indicates that Native Americans may have increased the extent of grasslands over the past 5,000 years through burning to reduce shrubs and prevent encroachment of forest species (Denevan 1992).

The first European explorers to enter the Great Plains were the Spanish who traveled from the south and southwest in the 1500s. Horses were probably first introduced to native people of the Great Plains through trade with the Pueblo Indians of New Mexico (Holzkamm 1981, Isenberg 1993). Throughout the 1600s, Native Americans were shifting and moving into other territories to the West resulting from the fur trade and European contact (Dolan 2010). The Dakota's (or Sioux) living in Wisconsin and Minnesota began moving west onto the Plains in North Dakota to take advantage of opportunities relating to the fur trade and as the introduction of horses increased (Holzkamm 1981). By 1690 horses were common on the Red River. The introduction of horses to the people of the northern plains transformed their way of life from living on the periphery of the grasslands relying on subsistence and bison to becoming nomads who relied almost solely on bison (Isenberg 1993). This transition also de-stabilized the tribes, creating small bands and undermining tribal authority. By 1740 the Dakota's and Chippewa's forced the Cheyenne from the Sheyenne River country. The Chippewa defeated the Dakota's on the Wild Rice River in 1807 (Lounsbury 1919). In 1867 two tribes of the Dakota's along with the Sissetonwan and Wahpetonwan tribes, were granted the Lake Travers Dakotah Sioux Reservation by the U.S. Government that contained a portion of Lake Tewaukon (USFWS 2000).

Peter Grant with the North-West Company established a trading post on the east side of the Red

River at the mouth of the Pembina River in 1794, and in 1800 Alexander Henry, Jr. began an exploration of the Red River District re-establishing the post and making Pembina the first permanent post in 1801 (Lounsbury 1919). The Great Northern Railroad was completed in 1886 and the Northern Pacific Railroad was completed in 1882 bringing an onset of homesteading settlers. Most of Sargent County had been settled by the late-1880s especially along the Wild Rice and Red Rivers (Bennet et al. 1908, Hutton et al. 1920). Many of the settlers were from Poland, although Germans and Scandinavians also represent a large portion of the population in addition to some native people and others coming west from eastern states. During the same period, the bison herds were decimated (Steckel and Prince 2001) and trappers had nearly extinguished the beaver populations of North Dakota (Lounsberry 1919, Dolin 2010). Agriculture in the Tewaukon NWR Complex region was first established in the late-1800s, consisting of wheat and oats, although flax and barley soon became important crops (Bennet et al 1908). Initially the wheat crop along the Red River was very productive, but waned overtime with farmers learning to rotate crops in order to sustain the soil. After about 1900, corn became increasingly important in the region and more livestock were produced (Hutton and Hendrickson 1920). As the number of cattle increased, dairies soon became prevalent with cream being the primary product distributed east to Minnesota via the railroad. Prairie grasses were initially utilized as hay until demand exceeded the available amount at which time cultivars such as timothy, clover, alfalfa, and millet were introduced (Bennet et al. 1908). By 1910 almost 90% of Sargent County was in farmland as native prairie was plowed and converted to cropland with little to no attention paid to soil type in relation to crop type (Hutton et al. 1920, Heidel 1986).

ESTABLISHMENT OF THE TEWAUKON NWR COMPLEX AND HYDROLOGIC AND VEGETATION COMMUNITY CHANGES

A complete history of the establishment of the Tewaukon NWR Complex is provided in the refuge CCP (USFWS 2000). The first efforts to create a NWR in the region began in 1934, when Executive Order 6910 established "Easement Refuges", whereby the USFWS acquired easements for flowage and refuge purposes. These easements were perpetual, and remained in private ownership. Original easement refuges were purchased on Lake Elsie, Wild Rice, and Storm Lake refuges; the USFWS subsequently divested the Lake Elsie easement refuge in 1998. Easement conditions allowed the USFWS to impound water, maintain refuge areas for migratory birds, and be managed as conservation demonstration efforts. The USFWS also applied for water rights to these easement lands including at Lake Tewaukon, Hepi Lake, Lake Elsie, Storm Lake and Wild Rice refuges. An 80-acre parcel was purchased outright by the USFWS along the Wild Rice River to be used for housing and a refuge headquarters. Initially, the refuge easement lands were managed from the Sand Lake NWR located 80 miles to the southwest in South Dakota.

In 1945, local landowners and sportsmen's groups supported additional protection of the Tewaukon region and desired improvements for recreational fisheries, especially at Lake Tewaukon. Public Land Order 286 in 1945 subsequently established Tewaukon NWR, and in 1946, 512 acres were purchased by the USFWS in fee title around Lake Tewaukon. After that first purchase, additional lands adjoining the parcel at Lake Tewaukon and at the nearby Sprague Lake Unit were acquired to enlarge the NWR to an eventual size of 8,363 acres. In 1956, the refuge became fully staffed and onsite staff assumed management responsibility and administration from Sand Lake NWR. The original management objectives for Tewaukon NWR, as stated in the 1962 Master Plan (USFWS 1962), set primary objectives: "1) to provide optimum nesting habitat for ducks and 2) to provide protection and food for fall and spring concentrations of Canada geese, and snow and blue geese." Secondary refuge objectives were: "1) to maintain balanced population of all resident wildlife species; 2) to provide for public observation of wildlife species in their natural environment; and 3) to provide limited day-use recreation including public hunting, where and when such activities are compatible with primary management objectives."

In 1960, the Tewaukon WMD was established to administer and encourage USFWS property interests in Richland, Ransom and Sargent counties. A primary objective of the WMD was to acquire WPAs subject to provisions of the Migratory Bird Conservation Act "for use as an inviolate sanctuary, or for any other management purposes for migratory birds." Public Law 85-585 later amended the Act to remove the requirement of inviolate sanctuary provision from WPAs, and as was further defined in (CFR) 50, effectively opened WPAs for hunting, trapping, and fishing. The Tewaukon WMD became comprised of fee-title owned WPAs, wetland easements and grassland easements. Throughout the history of USFWS acquisition of lands for the WPAs and easements, public and political support both local and statewide has been difficult. In the late 1970s, commissioners and the Governor of North Dakota prevented the USFWS from acquiring lands for the easement program partly through public meetings where they dissuaded landowners from entering into easement contracts. Acquisition was not approved for new lands to go under easement until 1993 in Richland County. Eventually over 14,000 acres in WPAs were acquired. Wetland easements were purchased from willing sellers to protect remnant and degraded wetland basins from draining, filling, leveling or burning. USFWS staff currently are responsible for managing about 35,000 acres of wetland easements. In 1998, grassland easements were added to the WMD to protect remnant prairie grassland areas from being converted to agricultural uses. Grassland easements can be grazed and hayed after 15 July and USFWS staff currently administers over 10,000 acres of grassland easements.

Water resources in the state of North Dakota came under water law in 1905 with the establishment of a State Engineer and the development of appropriations for beneficial use related to surface water, groundwater, residual/drain water, and non-contributing streams (Striffler 2013). In 1937 a State Water Commission was established to promote water development and investment of state capital. Water management districts were formed in 1973 and a reform of water management laws was initiated in 1981 to expand the power and authority of the water resource districts and improve their effectiveness. Irrigation for farmland was primarily through pumped and artesian wells. Artesian wells occur between 150 to 300 feet in depth. Open ditches were constructed in the early-1900s in order to help address drainage issues as well as areas with high alkalinity (Bennet et al. 1908). From 1917-23, the large drainage Ditch No. 11 (Fig. 2) was constructed to drain water from western areas of the Wild Rice River watershed including some permanently flooded wetlands: Bruns, Big, and Meszaros sloughs. Past maintenance of Ditch No. 11 upstream of Meszaros Slough is unclear, however, the ditch became silted in by the 1950s to the point that only high flows from the Bruns and Big sloughs were carried by the drain (Krapu 1996).

The creation of dams and reservoirs throughout the RRV and adjacent Drift Plain impacted surface water flows and wetland availability beginning in the early to mid-1900s. Lake Ashtabula, built in 1949 on the Sheyenne River, was formed by the Baldhill Dam, which has a storage capacity of 116,500 acre-feet of water. Orwell Reservoir on the Red River at Wahpeton can store 14,000 acre-feet , and Lake Traverse on the Bois de Sioux River can store up to 137,000 acre-feet of surface water. Flows in the Red River historically and currently are extremely variable with zero flows recorded on all tributaries except the Sheyenne River (Winter et al. 1984). Lake Tewaukon and Sprague Lake now have water-control infrastructure to maintain permanent water levels that provide fishing opportunities for the public. The 1962 Tewaukon NWR Master Plan addressed the general understanding between the local community and the USFWS to maintain the water levels and recreational use of Lake Tewaukon and Sprague Lake. Full pool levels inundate 1,047 and 199 acres, respectively for the two lakes. Although maintaining water levels at Lake Tewaukon tends to dampen downstream flow in the Wild Rice River, its capacity does not prevent downstream flooding along the river during wet periods and years. During the 1980s, the Sargent County Water Management Board initiated several maintenance projects that impacted the refuge and WPAs, including the clean-out project of Drain No. 11 and the rehabilitation of the four main dams on the Wild Rice River to help water flow during high flood events (Fig. 2). In the 1960s, four large dams were built across the Wild Rice River to impound and manipulate water levels for waterfowl management purposes; these areas include Cutler Marsh, Maka Pool, River Pool, and Pools 2-10 (GEI Consultants 2002a,b,c; Striffler 2013). The North Bay Dam on the Wild Rice River lies just north of the Tewaukon NWR boundary.

Immediately prior to establishment, lands in and around the Tewaukon NWR Complex were used predominantly for haying, livestock grazing, and crop production. Some lands were tiled to facilitate draining wetlands, which expanded available land for agriculture and promoted more diverse crop type production. After Tewaukon NWR was established, refuge staff began upgrading ditches and water-control structures that had previously been constructed as part of the refuge easement program and the U.S. Work Progress Administration under President Franklin Roosevelt's New Deal program. This early water-control infrastructure was originally built to help facilitate water management for waterfowl migration and breeding habitat, but was regularly damaged by ice dams and high flow pulses of the Wild Rice River. By the 1940s, many of the prairie pothole wetlands and slough/meadow areas had been ditched, dredged, and tiled along with being heavily silted in (USFWS, unpublished refuge annual narratives). About 100 acres of Tewaukon NWR was grazed and hayed in the late 1940s and several fields also had been converted to wheat, barley, and millet production. Permits were originally provided to various landowners for grazing and haying on Tewaukon NWR in the 1940s and 1950s, but over time, crop and hay/pasture lands were retired and planted in rotation to establish dense nesting cover (DNC) for nesting ducks or to re-introduce native prairie species (USFWS, unpublished refuge annual narratives).

After the Tewaukon WMD was created in 1960, water management, cultivation, grassland planting, and infrastructure development increased as staff were assigned to the various WPAs and easement lands (USFWS unpublished annual narratives). By the late 1950s, invasive weeds were expanding on all Tewaukon NWR Complex lands. Major problem plant species were leafy spurge (*Euphorbia esula*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), bull thistle (*Cirsium vulgare*) and a variety of non-native introduced grass species including quackgrass (*Agropyron repens*), Kentucky bluegrass (*Poa pratensis*), and smooth brome (*Bromus inermis*). Management of grasslands on refuge lands and easements became intensive in the 1970s as prescribed "controlled" burns, grazing, direct plantings, and chemical applications were made to restore native prairie, control invasive weeds, and create DNC (USFWS, unpublished annual narratives). In more recent years reed canary grass (*Phalaris arundinacea*), crown vetch (*Coronilla varia L.*), and Russian olive (*Eleagnus angustifolia*) also have become widespread on refuge lands (USFWS 2000).

Water-control infrastructure on Tewaukon NWR has been continually impacted by floods, which have regularly breached levees and "washed out" water-control structures (Table 6). A ditch "clean-out" project was initiated in 1984 and completed in 1986 by the Sargent County Water Resources District on (SCWRD) on Ditch No. 11 that lies north and west of the Tewaukon NWR. After the Ditch No. 11 clean-out occurred, local drainage of shallow wetlands and wet prairie/meadow areas was increased and landowners were able to farm many wetland areas for the first time in history. Overall, 2,093 ha or 6% of wetlands and 37% of lake surface water were severely impacted in Sargent County (Striffler 2013). Since 2011, new legislative processes have been in place to reduce the amount of time involved in processing new drainage tile permits in Sargent County, which has encouraged regional tile installation and land/wetland drainage. Throughout the twentieth century North Dakota has lost 49% of its wetlands (Dahl 1990, 2011; Millett et al. 2009).

National Wetland Inventory surveys mapped Tewaukon NWR units and WPAs as primarily freshwater wetlands and lakes (Fig. 23). The Tewaukon and Sprague Lake Units contain 14 impoundments and an additional 30 ponds that are managed using water delivery infrastructure including four dams; 71 water-control structures; and inputs from the Wild Rice River, LaBelle Creek, and three unnamed tributaries (Figs. 24, 25; Striffler 2013). Other water sources include drainage ditches that return water from agricultural fields to the Wild Rice River. Although many water-control structures are present on Tewaukon NWR, the relatively flat topography of management pools restricts water drawdown capability in many areas, and most wetland impoundment areas rely on evapotranspiration for seasonal drying (Striffler 2013). Spillways have been installed near some dams in areas that are consistently breached during flood periods, which allow the impoundments to fluctuate with river levels and prevent damage (see examples of regular repair of various water-control infrastructure in Table 6). Annual discharge in the Wild Rice River ranges widely depending on amount of snowpack, time of spring thaw, regional precipitation, and rates of surface water runoff. Gauge data from Cayuga on the Wild Rice River indicated an average discharge of 35 cfs from 1959-2012 with lows of almost 0 cfs and highs of 877 (some missing data – see Striffler 2013). Mean monthly flows vary from about 0 to 104 cfs. High flows generally occur in March and April with low flows in July and August and a smaller peak in September. The refuge holds water rights that are related to a specific amount (acre/feet) of storage within the lakes and sloughs as well as for seasonal use of some of that water and additional water from the Wild Rice River and tributaries (see Striffler 2013).

Table 6. Summary of water developments and management of Tewaukon National Wildlife Refuge 1939-2005 (taken from refuge annual narratives).

Year	Location	Development Activities
1939	Wild Rice River	Dam began leaking, repaired
	Roads	Riprapped two roads on the refuge
1942	Lake Tewaukon	Spillway repaired
1943	Lake Tewaukon	Bowl spillway west of county bridge across west arm of lake was damaged
	Wild Rice River refuge	Spillway on refuge washed out about 100' on east side
1945	Lake Tewaukon	Repair work on the lake dam completed; dike still in need of repair and have suggested the need for an emergency spillway
1946	Lake Tewaukon	New emergency spillway completed
1947	Lake Tewaukon	The county dumped a large amount of rock along the north shore at the causeway, were asked not to dump it there, future dumping will be on the south side of the causeway; Dam leaking and at a structure on the south end; main spillway was repaired
1948	Lake Tewaukon	Fish screen installed under road bridge below the old oxbow spillway
	Wild Rice River	New bridge being contructed just outside the refuge
1950	Lake Tewaukon	Four minor leaks in the spillway repaired
1953	Lake Tewaukon	Replaced bowl spillway inlet structure
1955	Lake Tewaukon	New structure being constructed
	White Lake	New structure constructed
1956	Gelinski Tract	Restored drained potholes and constructed a small pond for artesian flow
	Refuge	Opened up dense vegetation in sloughs by ditching; check dam dozed in to drain from slough by CR D on tract 60
1958	Lake Elsie	County installed new bridge, allows for faster equalization of water levels in two parts of the lake
1959	Storm Lake	Water control lift gate removed and attempted repairs
	Potholes	Pushed up small loafing islands in 4 dry potholes
1960	Lake Tewaukon	Fish barrier removed from bridge on CR D; will be remodeled and installed in Cutler Marsh spillway
	Potholes	Renovation project: 1. cut ditch through old dike at se corner of Cutler Marsh, culvert with gate installed, built 4 loafing islands in three sloughs created; all will be connected by culverts or ditches totaling 8 ac with 5' depth, 2. enlarged pothole and built a dike at west end of artesian well on tract 47 (west of headquarters), 3. built an earthen dam across the Clouds lake drainage, east of the old Thornberg house, will be 15 ac with 7' depth at dam; need to establish water rights for this area, 4. deepened 2 ac of low end of supplemental feed area in A 17, leveled fill around the deepened portion, hoping that they can plant around it, and 5. one other small pothole was deepened and loafing island constructed
1961	Refuge	Completed dike around artesian well flow west of temp HQ
	Storm Lake	Vandals broke the lift gate of the inlet structure
1963	Wild Rice River	Dam constructed just outside refuge boundary to the north has inundated river bottom
	Lake Tewaukon	Large hole eroded in rock and cement structure
	Potholes	Dug tile out of 8 drained potholes
	Maple River	Water control structure undercut and temporarily repaired

Continued next page

Year	Location	Development Activities
	Refuge	Constructed 13 check dams; created pond at artesian well
1964	Refuge	1/2 mile of road constructed east of HQ and entrance road to shop; 1/4 mile dike constructed for marsh flooding
	Pool 6	Dike and control structure constructed
	Pool 7	Dike widened and riprapped; temporary dike constructed
	Clouds Lake	24" culvert with slide gate installed, goes to pool 7; 12" culvert with slide gate installed to pool 9
1965	Lake Tewaukon	Installed new reinforced concrete structure; removed rubble masonry
	Refuge	Constructed one mile of road
	Clouds Lake	Constructed outlet structure; dug a channel from lake through pool 7
	Pool 3 and 7	Installed new culvert and dike
	Pool 5	Installed stoplog structure
	Sprague Lake Unit	Constructed 2 small channels out of the lake for marsh flooding
	Wild Rice River	Blasted a ditch from a slough to the river
	Maple River	Dam washed out
1966	Pool 6	Installed stoplog structure
	Pool 2A	Installed water control outlet
	Refuge	Installed 6 culverts in refuge roads; constructed one small impoundment southeast of Lake Tewaukon
	Pools 7A and 2A	Dikes raised and widened
	Pools 2, 2A, and 3	Constructed 18 nesting islands
1967	Sprague Lake Unit	Blasted a beaver dam on Wild Ricer River
	Hepi Lake (Cloud Lake)	Built approach and culvert into agricultural unit south of the lake
	Pools 2A and 3A	Raised and widened road and dikes around pools
	Refuge	Filled in spillway on dike 5 for road crossing; dozed dirt coffer dam out in front of dam 7N
	Potholes	Blasted 12 potholes northeast and northwest of HQ to deepen them
	Pool 12	Dug out discharge channel from the pool to dam 12; blasted 500' of downstream channel
	Pool 3	Dug 23 loafing islands in tension zone
	Pool 2A	Placed inlet structure in dike 3
	Lake Tewaukon	Construction of Dam 4 including 6 bay cement control structure and 680' of dike and new access road north of the lake, about 4,850' long
	Pool 4	Completed
1968	Nickeson	Repaired dike by filling the downstream borrow pit and adding fill (nw side of Pool 3)
	Sprague Lake Unit	Dozed ditches in potholes
1969	Lake Tewaukon	Water flowed over new Dam 4 and washed out structure which was repaired
	Sprague Lake Unit	Floods washed out three culverts under township road
	Nickeson	Pool 3 dike could not hold water, needs repair
	Refuge	Floods scoured a huge hole downstream of Dam 1 which was repaired
	Pool 5	Concrete collar poured around structure
	Pool 2A	Stoplogs leaking

Continued next page

Year	Location	Development Activities
1970	Potholes	Cleaned out 30 potholes with a dozer which had silted in over the years; installed a small control gate and dike on pothole near outlet of Wild Rice River from Lake Tewaukon; underground pipe installed from flowing well south of the office to pothole
	Nickeson	Dike built up and widened to level of Dam 4
1971	Pool 3	Leaking onto private land (Nickeson)
	Pool 6	Repaired water control structures
	Potholes	Stoplog control structures intalled on two potholes, one south of Sprague Lake and the other west of Sprague Lake
	Dikes 2A, 4, and 6	Riprapped washouts
	Wild Rice River	Beaver dams have impounded water in the channel
1972	Dikes 2A, 3A, and 6	Repaired from muskrat holes
	Nickeson	Dike was widened and old borrow pit filled and resloped
	Pool 3	Created 16 large nesting/loafing islands
	Pools 5 and 6	Dikes widened
1973-4	Hepi Lake (Cloud Lake)	Installed new and lower control gate
	Lake Tewaukon	Dozed gravel out of the lake and stockpiled it on west end
	Parker Bay	Dike constructed through the Bay
	Vogeler WPA	Plugged drainage ditches
	Klefstad, Heger, Gunneson WPAs	Plugged drainage ditches and dozed a new channel to get more water into the marsh
1975	Susag Land, Krause, Gainor, Evanson, Olson, and Klefstad WPAs	Plugged drainage ditches
	Parker Bay	Dug a channel out of the Bay to a control structure and riprapped dike
	Cutler Marsh	Dike road raised
1979	Maka Pool	Islands constructed
1980	Horseshoe Slough Unit	Banish dike with culvert and flap gate installed; Cut 2 small ditches with dike/culvert crossings to supply water from pools to 2 large isolated sloughs
	Sprague Lake Unit	Constructed three low dikes with 2, 16" culverts and flapgates on Wild Rice River in two old oxbows; constructed a 95' dike and installed a 16" culvert with flapgate in pothole
	Potholes	Installed ditch plug with raised culvert southeast of Parker Bay to divert meltwater into a pothole
	Lake Tewaukon	675' supply ditch cut to provide water during flood stage to small slough and then to Krause WPA slough, includes a 110' low dike and 48" CMP riser structure and a 70' low dike and structure into Krause slough
	LaBelle Creek	Repaired 330' dike to small slough and replaced flapgate
1981	Parker Bay	Water control structure leaking
	Hepi Lake (Pool 8)	Lowered feeder channel out of pool 8 into pool 7A; replaced slide gate strucutre wtiha 12" drop board riser; dug a deep trench through the pool bank to allow water flow into pool 9
	Horseshoe Slough Unit	Added two 48" riser board structures to supply culverts (pool 16) to move water from pool C to pool F and G
	Pool 2	Plow channel dug previous year did not work, trench cut and a PVC pipe installed

Continued next page

Year	Location	Development Activities
1982	Parker Bay	Rock riprap hauled to center of the bay to create a rock island for cormorant and pelican nesting
	Sprague Lake Unit	Closed off three culverts with dike and emergency overflow channel; will install a carp barrier on a new large single outle culvert and structure; Cut openings and deepened areas in cattail choked wetland and marshes (9 total deepened)
	Refuge	Artesian well at old Silseth farmstead was pipe west into a dry slough
	White and Mann Lakes	Rock piles placed in the lakes for loafing
1983	Cutler Marsh	Openings created in west end
	Pool 2A	Replaced 24" culvert and 48" CMP riser board structure and broadened dike; irregular openings cut in center of pool for cattail control
	Hepi Lake (Pool 8)	Lowered and enlarged north outlet structure; laid 575' of 12" PVC pipe northeast through hillside to spill in Wild Rice Rier
	Sprague Lake (Pool 14)	Carp barrier installed
	Pool 2	Installed 4" PVC pipe with control valve in east dike; small plug installed to trap water to overlfow south into west side of HQ pool
1984	West White Lake (Pool 11)	Installed one way flap gate on culvert
	Sprague Lake Unit	Sand bagged both sides of culverts
	Potholes	Five small plugs dozed across upland swales to form small duck pair ponds; dirt packed over three old culverts in three other areas
	Horseshoe Slough Unit	Ditch and 2 water control structures installed to supply and control water
	Mann Lake	Extension installed on culvert and dike expanded
1985	Potholes	Twenty old drainage ditches or natural swales had plugs installed; 2 small drainage ditches plugged on 88 ac BOR land
	Nickeson	DU installed riser board water control structure in existing dike
	Sprague Lake Unit	Three culverts in Pool A were replaced with squash culverts, fourth installed for Township; one dike repaired and a ditch plug raised
	Horseshoe Slough Unit	Large Squash culvert with riser board structure installed in Dike A; culvert and structure removed from road in pool A and installed to control water flow from pool C-east into pool C-south; culvert and structure to pool C-east was dug out and lowered to pass water under low flow conditions
	Pool 5	Subdivided to allow cattail in upper 5 ac to be flooded and a 24" culvert with board structure installed
	Pool 2A	Dike raised 2'
	Sargent County WPAs	Sargent County drain maintenance project included lowering road culverts and expandingthe drainage size from 90,000 to 144,000; they have deposited material in many wetlands along the drain which is 404 violation; EPA and USACE is involved
1986	Pool 3	DU completed project installing 46' culvert and 48" structure; also installed a structure in the Nickeson dike
	Pool 3A	New culvert and ditch repair
	Potholes	Five plugs put in; filled in drainage tiles to restore 3 wetlands
	Sprague Lake Unit	Ditch dug to 2 small wetlands
	Lake Tewaukon	Riprapped bank erosion
	Dike 6	Replaced structure
	Pool 2	North dike repaired and old structure removed

Continued next page

Year	Location	Development Activities
1987	Pool 4	Perforated pipe placed in Beaver dam
	Refuge	Sargent County replaced bridge with 2 large culverts
	Sprague Lake Unit	New control structure installed and a 500' dike constructed
	Pool 2	DU completed 705' dike dividing the pool
1988	Lake Tewaukon	Two Christmas tree reefs were put in the lake for fish habitat
	Refuge	Dam 1 repair completed including new spillway with erosion protection mat covered by top soil; three islands restored, dugout cattail areas around them
	Pool 5	Replaced 48" half round riser structure and 15" flapgate culvert; second one installed to allow more water around an island
1989	Lake Tewaukon	Severe damage to dike
	Parker Bay	Gates failed and replaced by stop log structure
	Sprague Lake Unit	Bank breached
	Refuge	New concrete added to Dam 1 structure; began splitting at the seam
1990	Pool 3	DU constructed dike
	Refuge	Old Bridge on dump ground road was removed and replaced with a 24" CMP
1991	Lake Tewaukon	East dike completed and south bank stabilization project initiated
1992	Lake Tewaukon	South bank and cemetery bank sloping and riprapping completed; more tree reefs for fish habitat created
	Olsen WPA	Removed ditch plug due to land owner issues
1995	Pool 2A	Riprap on dike and picnic dike area
	Lake Tewaukon	Hauled more trees to the lake for fish habitat
1996	Tewaukon WMD	Constructed 12 ditch plugs
1997	Lake Tewaukon	Installed 40 fish structures
1998	Parker Bay	Spillway completed
	Hepi Lake	Construction
	Pools 7A, 8, and 9	Repaired inlet and outlet on pool 9
1999	Pool 2 and 3	Completed construction of cross dikes
	Gainor WPA	Repaired dike
	Refuge	Concrete box culvert installed to replace existing one underneath CR 12
2000	Point Rd	Repair of flood damage completed
	Mann Lake	Replacement of water control structure and dike repair
2001	Nickeson	Dike breached and repaired
	Pool 9	Repaired outlet
2002	Sprague Lake and Lake Tewaukon	Completed bank stabilization projects
	Horseshoe Slough Unit	Replaced water control structures
	Pool 6	Structure and dike breached

Water quality entering the Tewaukon NWR Complex is influenced by contamination of drain water from surrounding agricultural areas and the application of groundwater pumped for irrigation. Groundwater throughout North Dakota contains high levels of total dissolved solids of approximately 2,500 ppm comprised of chloride, sulfate, sodium, and fluoride (Baker and Paulson 1967). Only the surficial glacial drift aquifers are reliably suitable for irrigation or domestic use (Winter et al. 1984). The Wild Rice River has been designated as "fully supporting, but threatened" resulting from levels of total fecal coliform and total daily maximum loading Priority 1 (Striffler 2013). These designations have been made based on use of the Wild Rice River as recreation. Water quality monitoring on the Wild Rice River and its tributaries indicate that contamination levels are highest just downstream of Lake Tewaukon and are caused by the accumulation of excessive nutrients from upstream sources (Striffler 2013). Nutrient influx may be apparent from blue-green algae outbreaks during periods when high flow events do not occur and water does not spill from the lake.

In addition to water management, other past habitat management on Tewaukon NWR has included physical manipulation of vegetation using agriculture, burning, mowing, disking, biological controls, and chemical treatments (USFWS 2000). Agricultural crops that have been planted on the Tewaukon NWR and WPAs include wheat, corn, soybeans, millet, alfalfa, and rye with rotations (Table 6). Figure 26 shows the various vegetation communities that currently exist on the Tewaukon NWR and WPAs. Recently, smooth brome appears to be the most common vegetation community occurring throughout the area. Currently, very few remnant tallgrass prairie sites still exist in the RRV. In 1983, Heidel (1984) found five healthy bluestem prairie sites, with 21 others that had some native dominant bluestem composition but were degraded or contained significant amounts of other non-native plant species. The historical extent of tallgrass prairie in the RRV has decreased to less than 1.2 km^2, a 10,000-fold loss (Heidel 1984). Mixed-grass prairie has decreased in extent by up to 30-99% depending on location from west to east, respectively (Gannon et al. 2011). Introduced cool season grass species such as smooth brome and Kentucky bluegrass have invaded many of the native remnant prairie stands and also dominate many grassland fields on the Tewaukon NWR Complex (Gannon et al. 2011). Historically, fires occurred at some frequency throughout these areas, which promoted prairie and savanna communities. Some information exists that fire frequency would have been greater in Presettlement periods, with frequencies in eastern North Dakota occasionally up to 20 years between natural lightening fires (Higgins 1984). Most of these fires naturally occur during July when thunderstorms are more frequent although they may occur any time during the frost-free season (Higgins 1984). Responses of the tallgrass and mixed-grass prairies to fire and disturbance may be different (Hulbert 1984) given their physiological and geographical adaptations. Grassland restoration projects have been conducted on the refuge and on the Hartleben and Aaser WPAs (USFWS, unpublished refuge annual narratives). Projects have retired cropland, planted native grasses, and incorporated burning and grazing to promote and maintain these historic prairie sites. Unfortunately, conversion of the historic vegetation communities has promoted invasive weed species. Control of invasive species, including leafy spurge and Canada thistle, on refuge and WPA lands has been conducted over time at various levels incorporating herbicide treatments and biological controls.

Two small areas on the Hartleben WPA meet criteria for a Research Natural Area (RNA) designation. RNA sites typically have retained a more natural historical condition including topography, hydrology and vegetation community composition and structure. At the Hartleben WPA, these potential RNA sites support wet prairie communities and are being considered for designation as RNAs (USFWS 2000).

Keith Frankki, refuge staff

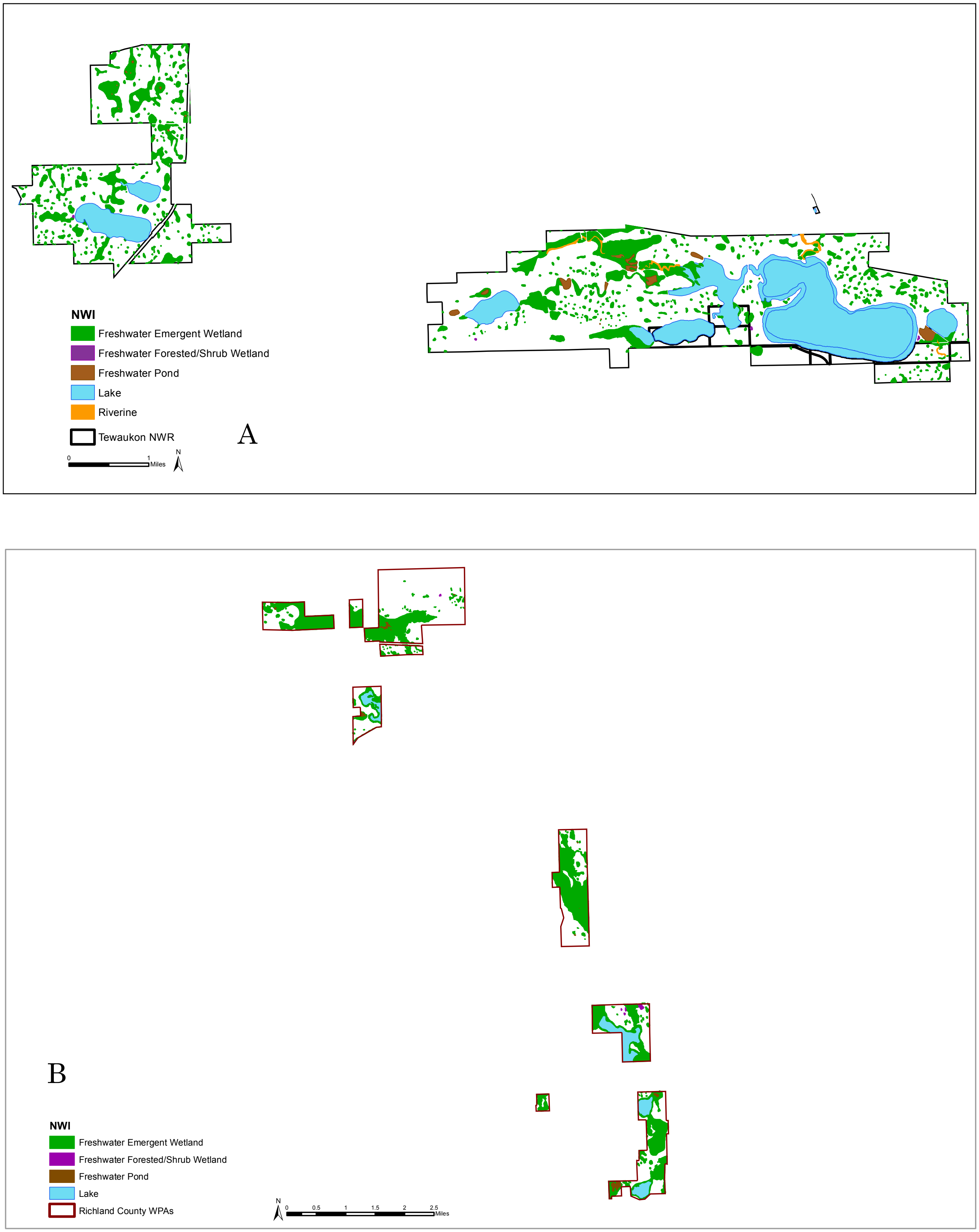


Figure 23. National Wetland Inventory maps for: a) Sprague Lake and Tewaukon National Wildlife Refuge units; and b) Hartleben WPA complex sites (from USFWS, http://www.fws.gov/wetlands/Data).

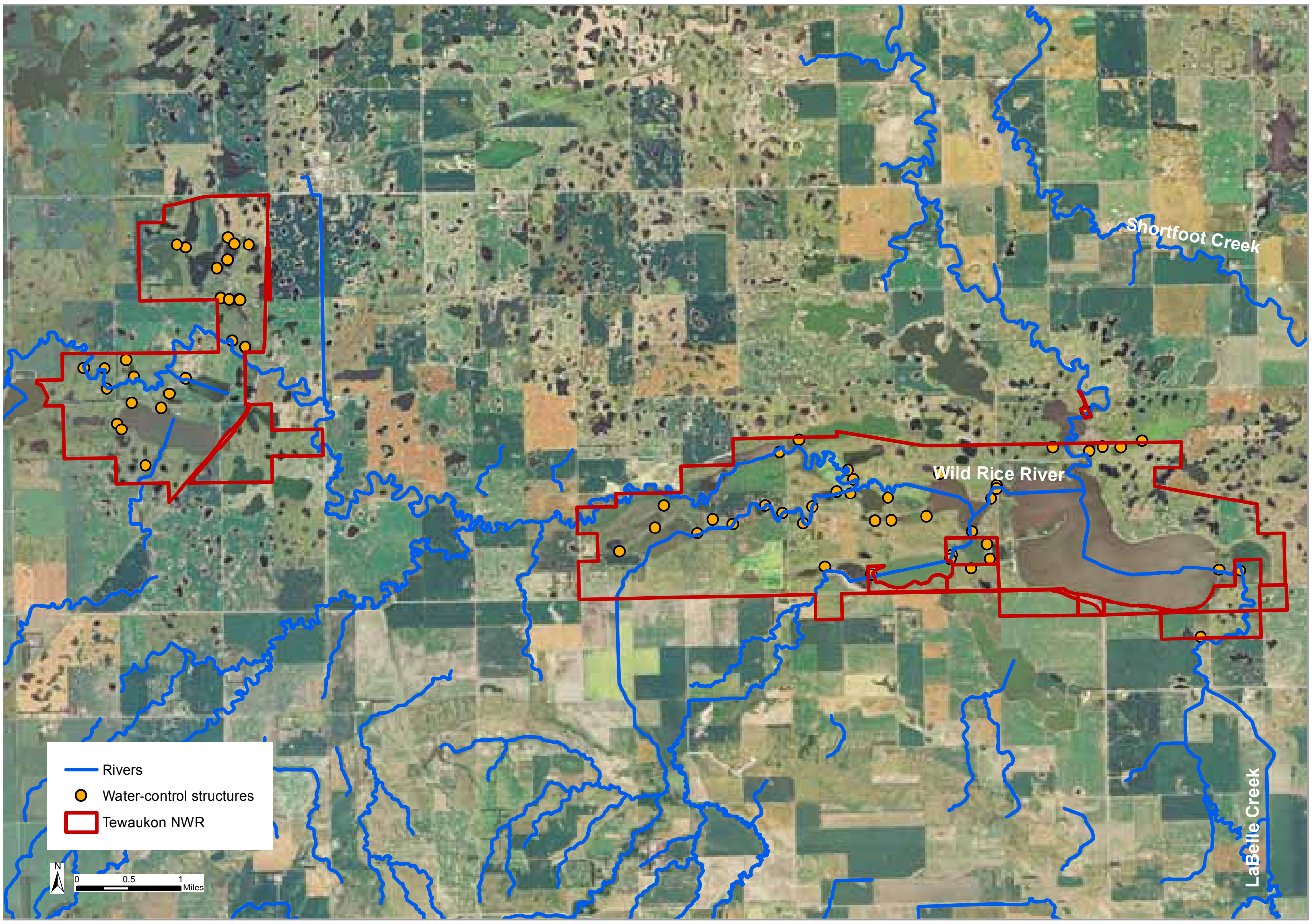


Figure 24. Location of water-control structures on Sprague Lake and Tewaukon National Wildlife Refuge units (data from USFWS).

Keith Frankki, refuge staff

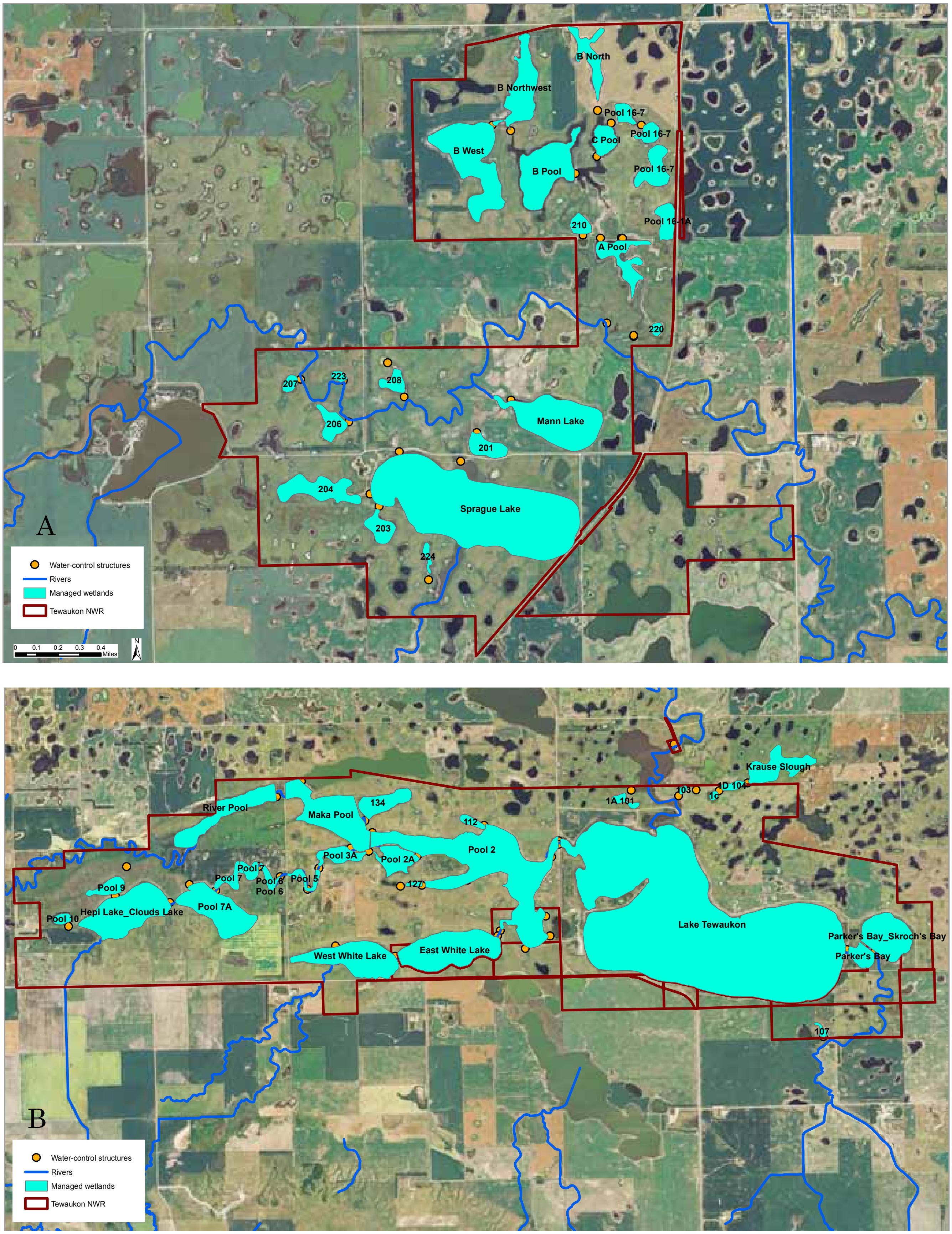
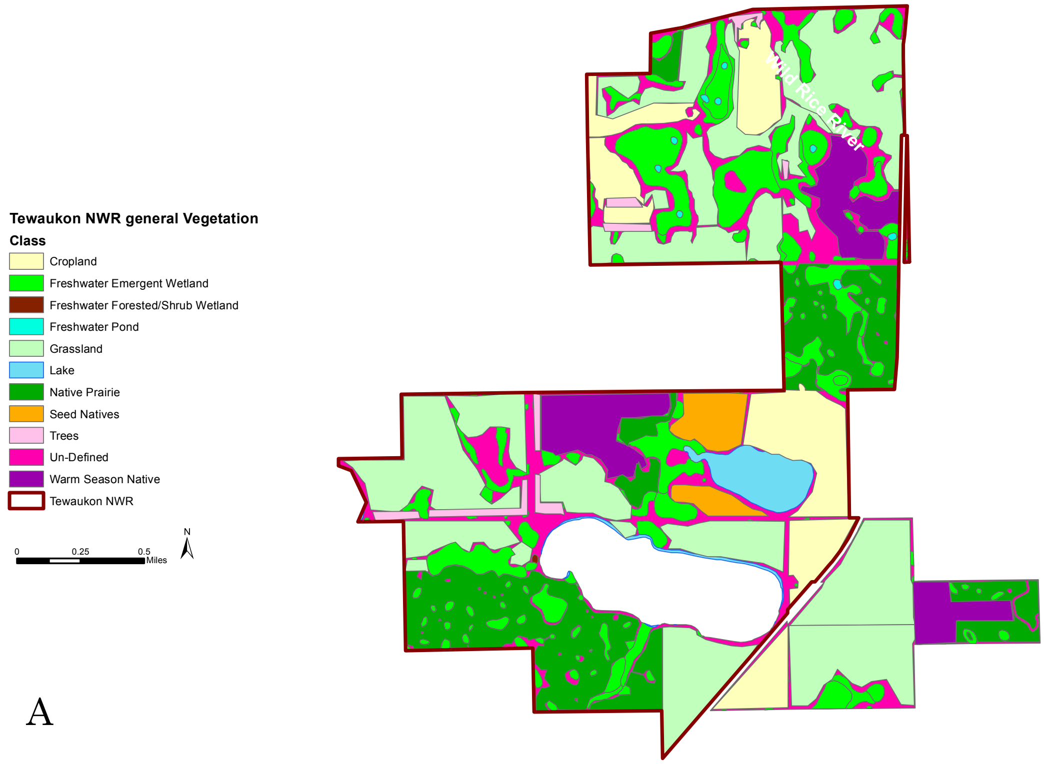
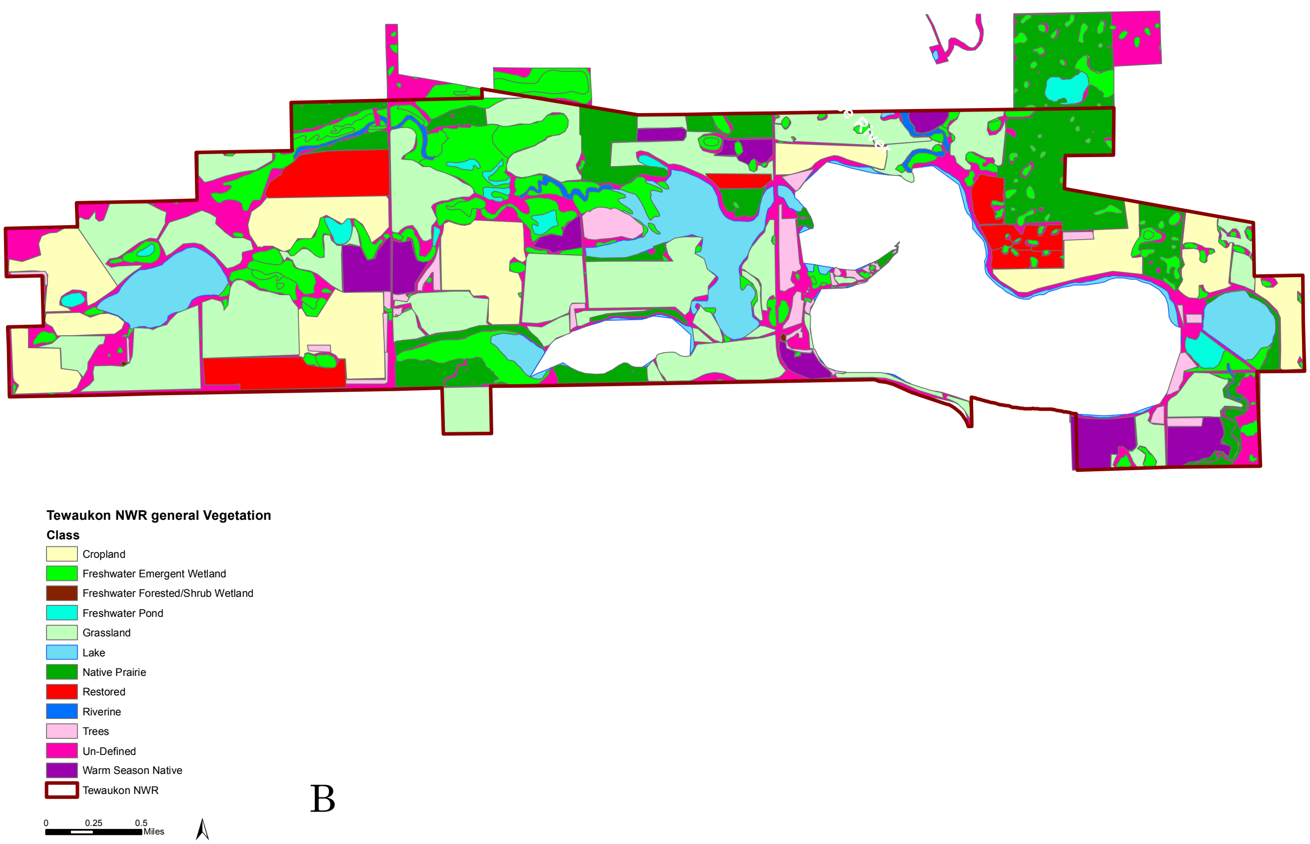


Figure 25. Managed wetlands on: a) Sprague Lake; and b) Tewaukon National Wildlife Refuge units (data from USFWS).

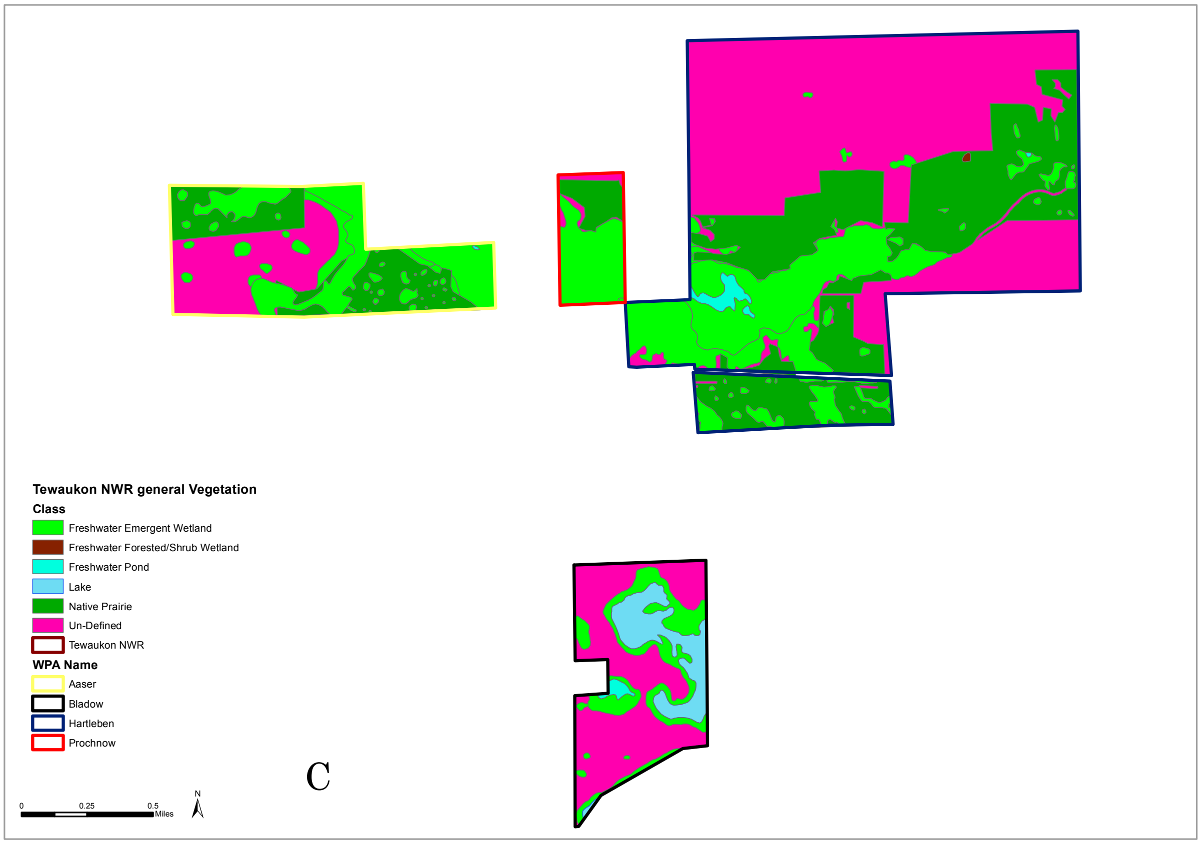


A



B

Figure 26. 2012 Landcover vegetation class maps for: a) Sprague Lake Unit; b) Tewaukon Unit; c) Hartleben, Prochnow, Aaser and Bladow WPAs; and d) Biggs, Gunness, and Korth WPAs (data provided by Tewaukon NWR staff).



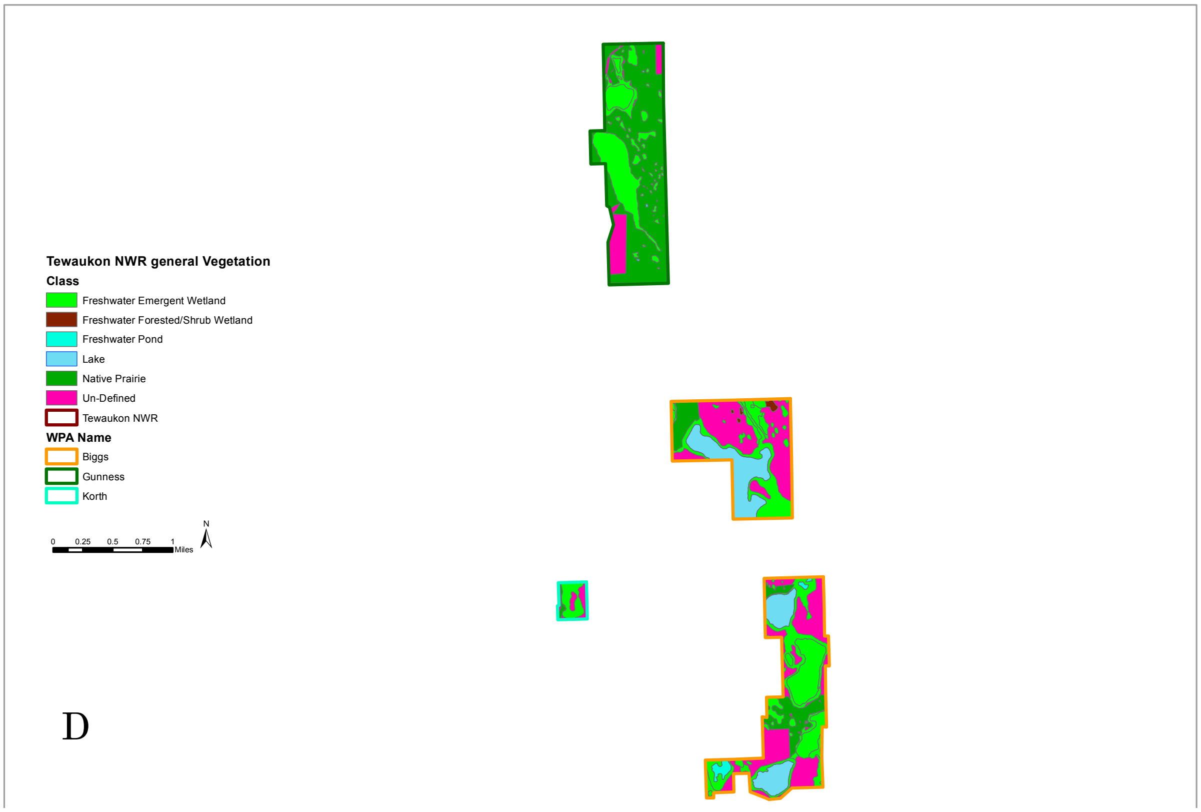


Figure 26, continued. 2012 Landcover vegetation class maps for: a) Sprague Lake Unit; b) Tewaukon Unit; c) Hartleben, Prochnow, Aaser and Bladow WPAs; and d) Biggs, Gunness, and Korth WPAs (data provided by Tewaukon NWR staff).

Kristine Askerooth, refuge staff

Keith Frankki, refuge staff

OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

The Tewaukon NWR Complex area historically was dominated by tall and mixed-grass prairie imbedded with numerous prairie pothole wetlands, a few scattered larger relict glacial lakes, and some narrow riparian forest bands along the Wild Rice River and along Lake Tewaukon (e.g., Moberg 1952, Gantt 1980). Annual surface water inputs to the Wild Rice River watershed, including potholes and larger relict glacial lakes, were highly pulsed and dynamic in spring and late summer depending on annual snowpack and melt water runoff and local precipitation. Glacial lakes typically contained some water throughout the year, but lake edges were drawn down in summer and early fall, and during dry years, the entire lake basin was occasionally dry. Larger and deeper pothole wetlands had semipermanent water regimes and during wet years these basins may have periodically retained some surface water year round. Seasonal and interannual dynamics of temperature, snowpack, and summer rains caused significant annual variation in amount and distribution of flooded wetland area and corresponding PEM, seasonal herbaceous, and wet prairie/meadow vegetation. Extensive areas of tallgrass prairie was present throughout the eastern part of the Tewaukon NWR Complex around potholes and on moraine hills; areas of higher elevation hills on the Sprague Lake and Tewaukon NWR units transitioned to mixed-grass prairie.

The primary ecosystem changes in the larger-scale RRV and adjacent glaciated Drift Plain that surrounds and includes the Tewaukon NWR Complex have been: 1) extensive conversion of tall and mixed-grass prairie and interspersed pothole wetland basins to agricultural uses; 2) planting of trees as windbreaks; 3) change in regional surface and groundwater flow patterns and wetland/river hydrology from land conversion, field tiling, draining of wetlands, and water- and flood-control infrastructure; 4) suppression of fire and changes to native herbivory patterns in the prairies; and 5) introduction of many invasive and nonnative species of plants. Major contemporary ecosystem changes specific to Tewaukon NWR complex lands have been: 1) alterations to the distribution, flow, and chronology of surface and groundwater; 2) conversion of native prairies to cropland and non-native plant composition and uses; 3) drainage and conversion of wetland depressions; 4) alteration of frequency, duration, intensity, and seasonality of physical disturbance processes including fire and ungulate grazing; 5) contamination of river and drain water from agricultural activities and groundwater pumping; and 6) introduction of many invasive and nonnative species of plants.

Starting with the establishment of USFWS Easement refuges in the 1930s, the vision for the Tewaukon NWR Complex was to protect and restore a part of the PPR tallgrass and mixed-grass prairie-wetland ecosystem. This prairie-wetland ecosystem once covered about 190 million acres from southern Texas to southern Canada and was the dominant vegetation community across the eastern Great Plains of the United States during Presettlement times (Bailey 1995, Steinauer and Collins 1966). The land and hydrology changes mentioned above have reduced this historically large and highly productive ecosystem to a small fraction of the historical area. Of the estimated 4.75 million acres of tallgrass prairie present in North Dakota in the Presettlement period, less than 275,000 acres remains. Clearly, establishing the parts of the Tewaukon NWR Complex including wetland and grassland easements, WPAs, and fee-title NWR lands has provided an opportunity to protect, restore, and manage some small remnant parts of this prairie ecosystem. It has been estimated that the Tewaukon WMD area still retains about 118,700 acres of native prairie grassland (USFWS 2000). Currently, the U.S. Forest Service manages about 50,000 acres of grassland in the Tewaukon WMD region as the Sheyenne National Grasslands, the USFWS owns fee-title to about 3,700 acres of native grassland, and The Nature Conservancy owns another 1,100 acres of native grassland. Consequently, about 60,900 acres of native grassland remain in private ownership, with about 10,000 currently protected in USFWS grassland easements. Protecting the other ca. 50,000 acres of private native grassland is a conservation priority, as is restoring other former areas of native prairie that have been converted to other uses or that now are heavily invaded by introduced grasses such as smooth brome and Kentucky bluegrass.

The Tewaukon NWR Complex was established to increase migratory bird production, with an emphasis on waterfowl. Secondary goals of refuge establishment, and more consistent with this HGM evaluation, were to: 1) preserve, restore, and enhance a diversity of indigenous plants and animals of the RRV prairie-wetland ecosystem and 2) to promote a lasting land use ethic in the RRV by becoming an educational model for land and watershed stewardship (see e.g., similar discussion of contemporary objectives for Hamden Slough NWR, also within the RRV, USFWS 1991). Restoring the integrity of the prairie-wetland landscape in the Tewaukon NWR region will require: 1) expanded protection and restoration of native prairie and imbedded pothole wetlands and glacial lakes on refuge lands and easement areas, 2) indirect involvement with improving and restoring surrounding private lands in the Wild Rice River watershed, and direct active management of prairie and wetland communities on Tewaukon NWR and WMD lands. A major challenge for future management of Tewaukon NWR Complex lands will be to determine how to restore endemic prairie plant and animal communities, and their sustaining ecological processes, given incomplete ownership, altered local and regional hydrology, land use, and invasive species. Past management of the refuge primarily has been directed at restoring small pothole wetlands, converting some agricultural lands to native prairie and introduced DNC-type grassland cover for nesting ducks, and developing water-control infrastructure in pothole wetlands and larger relict lake areas along the Wild Rice River. Water management of the larger lakes such as Tewaukon and Sprague lakes has been constrained by refuge establishment policy, especially the desires of local communities to maintain adequate water levels year round to establish and support a recreational fishery. Further, some water management of wetlands has been somewhat passive and constrained by structure and topography gradients, but with occasional drawdown and vegetation manipulation to enhance waterbird, especially duck, production. Future management issues that affect timing, distribution, and movement of water on the NWR (including in and through important small seasonal and large semi-permanent wetland basins) must consider how, and if, they are contributing to desired objectives of restoring native communities and their processes on the refuge.

This hydrogeomorphic study is an attempt to evaluate restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at (and near) Tewaukon NWR and the Hartleben WPAs. Other areas within the Tewaukon NWR Complex such as Wild Rice and Storm Lake Easement refuges were not specifically included in this HGM evaluation because of the limited management capability on those sites. The Tewaukon NWR Complex provides key resources that meet life history requirements of many plant and animal species in the RRV. The signature relict glacial lake basins, moraine potholes, and interspersed prairie at Tewaukon NWR are especially critical components of this ecoregion that need protection and restoration. The Tewaukon NWR Complex also provides many opportunities for public uses. These public uses are important values of the refuge, but they must be provided and managed within the context of more holistic regional landscape- and system-based management.

This study does not address where, or if, the many sometimes competing uses of the refuge can be accommodated, but rather this report provides information to support The National Wildlife Refuge System Improvement Act of 1997, which seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999, Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Meretsky et al. 2006). Most of the CCP's completed for NWR's to date have highlighted ecological restoration as a primary goal, and choose historic conditions (those prior to substantial human related changes to the landscape) as the benchmark condition (Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historic conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s)" (USFWS 2001).

GENERAL RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

Critical issues for future management and expansion of the Tewaukon NWR Complex include: 1) protection and restoration of diverse native grassland communities that include imbedded pothole depressions; 2) restoration of natural local and regional surface and groundwater flow patterns and regimes that control the hydrology of the Wild Rice River and its tributaries and the extensive pothole wetlands imbedded in the historic prairie landscape; and 3) maintenance and management of larger wetland lakes within constraints of refuge establishment conditions, water rights, and local policy issues. All of these future management considerations must seek to define the role of the refuge lands in a larger landscape-scale conservation and restoration strategy for the RRV and Drift Plain region. Many management actions for Tewaukon NWR were identified in the refuge CCP in 2000 (USFWS 2000), and this HGM report helps provide additional evaluation to support and expand these CCP recommendations.

This HGM report evaluation for Tewaukon NWR seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be reversed and restored to historic and functional conditions within a "new desired" environment. This HGM approach also provides a basis to help future efforts evaluate the NWR within the context of appropriate regional (e.g., the broader RRV) and continental (e.g., PPR) landscapes, and helps identify the "role" of Tewaukon NWR Complex lands in meeting larger conservation goals and needs at different geographical scales. In many cases, restoration of functional ecosystems on NWR lands such as at Tewaukon and Sprague Lake Units and the Hartleben WPAs can help an individual land tract serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

The HGM evaluation process is not species-based, but rather seeks to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of endemic species, both plant and animal, and other ecosystem functions, values, and services. Management of specific land parcels and refuge tracts should identify key resources used and needed by native species, and support special needs for species of concern. The development of specific management strategies for Tewaukon NWR requires an understanding of the historic context of the region relative to what communities naturally occurred there, the seasonal and interannual dynamics and thus availability of community resources, and when and where (or if) species of concern actually were present on the tract and what resources they used. Contemporary management also is based on understanding the regional context of the site, both historic and present, by understanding how, or if, the site historically, or currently, provided dynamic resources to species of concern – and attempt, where possible to continue to provide key resources in naturally occurring times and distribution consistent with meeting life cycle requirements necessary to sustain populations. Consequently, recommendations from the HGM evaluation in this study are system-based first, with the goal of maintaining the ecosystem itself, with the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern can/will be accommodated. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes in which they sit (Fischman and Adamcik 2011). Obviously, some systems are so highly disrupted that all natural processes and communities/resources cannot be restored, and key resources needed by some species may need to be replaced or provided by another, similar habitat or resource. However, the primary objective for refuges should be to attempt to restore the basic features of former functional landscapes.

The primary ecological process that controlled the Tewaukon ecosystem was seasonally and annually dynamic precipitation and runoff within the Wild Rice River watershed. During wet years, local and regional precipitation increased and filled large and small wetlands, and overflow waters subsequently drained to the Wild Rice River and then onto the Red River. During dry years, less surface and groundwater discharge drained into wetlands, causing them to dry or have lower water levels; in these years little runoff probably occurred to the Red River. The ecological importance of both seasonal and interannual hydrological dynamics of flooding and drying are well documented in prairie wetlands (e.g., van der Valk 1989, Murkin et al. 2000) and help maintain physical and biotic attributes of this ecosystem. Additionally, seasonal and interannual disturbance from herbivory (and associated trampling), fire, and wind are important events that sustain tallgrass prairie communities by recycling nutrients, removing detritus and thatch, deterring woody plant invasion, and creating germination/regeneration sites for grasses and forbs (Kirby et al. 1988, Sims 1991).

Collectively, the interspersion of prairie and pothole habitats at Tewaukon supported a diverse and highly productive community assemblage of plants and animals. A few larger relict glacial lakes/wetlands along the Wild Rice River (such as Hepi, Cutler, Storm, and Tewaukon lakes/marshes) contained more permanent water regimes, albeit with dynamic drying edges. Other deeper moraine potholes typically had semipermanent water regimes; and still other small prairie potholes had seasonal or ephemeral water regimes. This regional complex of wetlands with varied hydrologic regimes provided complexes of diverse resources to animals depending on wetlands. Adjacent interspersed tallgrass prairie further offered food, cover, and other resources to a wide diversity of seasonal and resident species.

Major ecosystem degradations in the Tewaukon NWR Complex region are caused by both systemic and local issues. Certain ecological degradations can be directly addressed by the USFWS on existing fee-title lands at Tewaukon NWR and WPAs, while other problems will require coordinated efforts and solutions within the larger watershed landscape. Clearly, many ecosystem restoration and management issues depend ultimately on protecting and restoring the remaining lands within the approved Tewaukon WMD boundary. Given this completed protection goal, interim management and restoration should be designed to facilitate landscape-scale prairie restorations for a larger future benefit (e.g., Samson and Knopf 1996). Recognizing the above factors, and based on the HGM context of information obtained and analyzed in this study, we believe that future conservation efforts at Tewaukon NWR and the Hartleben WPAs should seek to:

1. Maintain and restore the physical and hydrological character of lands within the Wild Rice River watershed, especially in the Tewaukon WMD.
2. Restore the natural topography, physical integrity of water flow patterns, and water regimes in prairie, relict glacial lakes, and prairie potholes within the Tewaukon WMD region.
3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relationship to topographic and geomorphic landscape position.

The following general recommendations are suggested to meet these ecosystem restoration and management goals:

1. Maintain and restore the physical and hydrological character of lands within the Wild Rice River watershed, especially in the Tewaukon WMD.

The Wild Rice River watershed is an important contributor to, and recipient of, resources and hydrology of the larger Red River watershed. Restoration of sustainable plant communities and ecological processes (such as flood storage and groundwater recharge) at Tewaukon NWR will require changes in inputs and exports of water, sediments, and nutrients to, and from, surrounding lands, which now primarily are in intensive agricultural production. Restoring the hydrology of the Wild Rice River watershed, and wetland systems within the Tewaukon NWR Complex, will require the restoration of more natural patterns of water entry into, through, and exiting the area. Currently, the largest deterrents to restoring regional hydrology are:

- accelerated surface water runoff, including higher nutrient and sediment loading, from intensively farmed agricultural lands.
- reduced infiltration and recharge of groundwater sources from agricultural tile drainage, drainage of pothole wetlands and wet prairie/meadow areas, and accelerated surface water runoff from agricultural and grassland fields.
- altered topography, and an extensive network of roads and ditches throughout the watershed.
- the existence and maintenance of the Ditch No. 11 drainage system.

While the root causes of these watershed degradations are not under the control of the USFWS, nor can the Tewaukon NWR Complex lands protect the entire Wild Rice River watershed area, the USFWS should continue to encourage private lands programs, and work with regulatory and drainage district entities, to create more sustainable land uses, and restore more natural hydrology, especially water flow and drainage patterns and amounts to the region. An important, yet mostly uncertain, consideration for future conservation and management strategies at Tewaukon NWR (and other Upper Midwestern landscapes) is how climate change may alter future hydrological conditions, and subsequently affect regional land uses and vegetation communities. Generally, climate data suggest a trend toward increasing precipitation (number of days with precipitation, mean annual amounts, timing, etc.) in the Upper Midwest (see Striffler 2013:65) and other models suggest gradual increases in long-term mean temperature regimes. If climate conditions continue to become warmer and wetter in the region, more water may discharge through the Wild Rice River and enter Tewaukon NWR unless regional land uses and water discharge/runoff can be mediated. Consequently, engaging conservation programs both on and off the refuge to restore native grassland, reduce surface runoff and groundwater discharges, restore the integrity and storage capacity of small and large historic wetlands, and restore wetland vegetation in the region is important. In this light, conservation programs could entail additional conservation easements and restoration of native wetland and prairie habitats, expansion of WPAs and wetland and grassland easements, support for removal of tile drains, restoration of surface sheetwater flow, and restoration of pothole wetlands to retain and slow regional surface water runoff that contributes to downstream flooding and nutrient loading issues ultimately in the Wild Rice River and its contribution to the larger Red River system.

2. Restore the natural topography, physical integrity of water flow patterns, and water regimes in prairie, relict glacial lakes, and prairie potholes within the Tewaukon NWR Complex.

The ecological diversity and productivity of the historical Tewaukon NWR region was created and sustained by a diverse glacial moraine geomorphic/topographic surface that was "hydrated" by seasonally and annually dynamic precipitation and runoff within its local watershed. The topographic and geomorphic/soil characteristics of this region created complex, often highly connected, mosaics of pothole/upland prairie elevations and within-basin ground and subsurface water pathways with site-specific hydrology. This unique heterogeneity of topography and water likewise supported a diversity of local vegetation communities and resources that were used by many animal assemblages.

The more localized watershed and hydrological regime of the region became altered with the construction of the large Ditch No. 11 drainage system infrastructure, construction of many other small drainage ditches, and conversion of much of the regional prairie ecosystem to agricultural uses. Collectively, these and associated land changes altered timing and extent of surface and groundwater discharges into the Wild Rice River and at least partly drained some larger relict glacial lakes; drained and caused greater drainage connectivity to local potholes and their drainages; and converted most native tallgrass prairie uplands to intensive agricultural production. In effect, much of the Tewaukon NWR site eventually became a hydrological "flow-through" system, as opposed to its historical water receiving and storage functions and processes. The change to a more flow-through system has obvious impacts on surface and groundwater movement from the area and accelerated and increased surface water flows into the downstream Red River drainages. Consequently, at both local and regional scales, it is desirable to slow and reduce accelerated surface water discharge from the Tewaukon region that currently is contributing to greater flooding issues, and associated economic and ecological damages, in the Red River system. This need may be even further justified if climate change in the region leads to more long term annual precipitation and runoff in the region.

As stated in goal #1 above, many of the factors that affect the Tewaukon NWR Complex are outside of current fee-title lands of the refuge and WPAs, and ultimately, more widespread watershed-scale changes in land and water use will be needed to restore functions, values, and processes in the region. Despite the limited fee-title USFWS ownership, restoration and active management of many landscape attributes, communities, and processes is possible on the refuge and surrounding lands and easement areas. Past efforts to restore hydrological inputs and exports, via ditch plugs, etc., for individual potholes have been very important and helpful to achieving larger, more landscape-scale, benefits for this regional ecosystem. In the future, more comprehensive restoration of hydrological regimes, landforms, and native community type and diversity will be needed to more completely allow refuge lands to contribute to ecosystem sustainability and productivity.

Generally, restoration of the physical and biotic diversity and productivity of the Tewaukon ecosystem will require at least some restoration of natural topography, especially reconnecting natural surface and groundwater flow pathways, restoring individual wetland basin watersheds, reducing drainage and flow through of larger relict glacial lakes, and restoring native distribution and type of vegetation communities (e.g., Galotowitsch and van der Valk 1994). Further, active management of both wetlands and uplands should seek to emulate natural patterns of flooding and drying, disturbance events (such as fire, herbivory, flood/drought), and dynamics of vegetation assemblages.

3. Restore and maintain the diversity, composition, distribution, and regenerating mechanisms of native vegetation communities in relationship to topographic and geomorphic landscape position.

The major vegetation communities historically present in the Tewaukon NWR Complex ecosystem were distributed along geomorphic, soil, topographic, and hydrology gradients. The HGM-based mapping of Presettlement vegetation communities identified the locations of historical communities and their juxtaposition (Table 5, Fig. 22). Each community has a unique suite of physical and ecological attributes and processes, summarized below.

Upland elevations on much of Tewaukon NWR Complex lands had well-drained soils dominated by silt loams and contained mesic tallgrass or mixed-grass prairie. These prairies commonly had diverse stands of grasses such as big and little bluestem, needle-and-thread, and sideoats grama; sandy soils in these locations usually contained prairie sandreed. Many forbs were present in these habitats and woody vegetation was limited to a few shrubs that were controlled by regular fire and occasional intense browsing or trampling by elk or bison, respectively. Onsite precipitation, especially winter snow, was the primary water input to these communities and water infiltrated soils quickly to recharge local shallow aquifers and to discharge as seeps into drainages and local potholes. Higher drier elevations in the west part of the Tewaukon NWR Complex historically supported a transitional prairie from the tallgrass to mixed-grass assemblages. This mixed-grass community contained more green needlegrass, bearded wheatgrass, and porcupine grass than tallgrass sites, but had many similar forb species. Currently, only a few remnant native prairie stands occur on the Tewaukon NWR Complex and some grassland fields are heavily invaded by introduced smooth brome and Kentucky bluegrass.

Lower slopes on moraine hills graded to wetland depressions and moraine hill valleys. These sites often had more fine-texture loam and some clay soils and soil moisture was about equal to onsite precipitation creating a wet-mesic environment that supported wet-mesic prairie habitats. Wet-mesic prairies were dominated by big bluestem, Indian grass and water tolerant forbs such as New England aster, Culver's root, and Virginia mountain mint. Wet-mesic prairie sites were hydrated by local onsite precipitation and some surface sheetwater runoff from higher elevation moraine hill slopes. Fire burned through these prairies during dry periods and, along with local herbivory, maintained the grass/forb dominated community.

Moraine hill valleys and upland edges of wetland depressions contained wet prairie/meadow communities dominated by numerous herbaceous and some grass species such as bluejoint grass, river bulrush, prairie cordgrass, spikerush and water horehound. Many of the former wet meadow areas now contain many non-native species. Wet prairie/

meadow sites had seasonal inundation for short periods, usually from sheet flow of surface water running off of, or seeping from, moraine hills. During dry years, wet prairie/meadow sites may have had only short periods of water flow across them, if at all. In contrast, during wet years, these sites apparently had more prolonged inundation. Fire was rarer in wet meadows compared to upland prairies because of saturated soils during spring and into summer; but during dry years wet prairie/meadow vegetation likely burned, at least in part.

The glacial moraine and historic RRV landscape at the Tewaukon NWR Complex contained numerous pothole wetland depressions. These potholes ranged from very small and shallow depressions that received surface water inputs for short periods during spring rains and snow runoff, to larger deeper depressions that received more regular and extended runoff in most years. Most potholes on the Tewaukon NWR Complex were terminal basins that captured local water runoff and they did not discharge water to other basins or drainages (by water overflowing the basin capacity) except during very wet years. Consequently, the water regimes in the potholes ranged from ephemeral to semipermanent flooding. Concentric bands of vegetation were present in the potholes depending on the depth and degree of water permanence. In deeper potholes, the deepest center areas contained open water and aquatic plants surrounded by emergent and then herbaceous plant zones that ended in wet prairie species. Interannual dynamics of flooding and drying caused the bands of pothole wetland vegetation to shrink during dry periods and expand during wet years. Fire occasionally ranged into potholes depending on its water regime, wetness of the year, and proximity to prairie uplands that supported fire.

A few larger relict glacial lakes also historically occurred on Tewaukon NWR Complex lands. These larger depressions are defined by their residual old peat-muck type soils deposited in former glacial outwash periods and included the namesake Tewaukon Lake along with Sprague, Hepi, White, and other lakes. Runoff from the watershed and overflow from some potholes (at least in wet years) drained into these larger deeper wetlands and created nearly permanent water regimes in the deepest center locations surrounded by wide concentric bands of emergent, herbaceous, and wet meadow species similar to potholes. Some lakes did overflow into Wild Rice River in most years and others likely did during wet years. Interannual wet-dry cycles sustained the wetland-zoned vegetation of the lakes and recycled nutrients, provided germination sites for some plant species, and provided essential resources to a host of animals, especially waterbirds (e.g., van der Valk 1989, Murkin et al. 2000).

Restoration of types, distribution, and processes in the vegetation communities on Tewaukon NWR Complex lands first requires an understanding of the HGM attributes associated with the community, and then second, requires managing areas of the refuge for the appropriate attributes, especially emulating former hydrology patterns and locating communities on appropriate geomorphic, soil, and elevation locations. The location of potholes and the larger relict lakes at Tewaukon NWR are clearly identified by historic maps and current LIDAR topography data. Zones of wet meadow and prairie types require more complete soil, topography, and hydrology information such as provided in Fig. 22. Restoring native complexes of all wetland and upland habitats will require restoring landforms and hydrology as mentioned previously. Future management of water regimes in wetlands and disturbances in upland prairies must seek to emulate natural patterns and include a more comprehensive management plan specific to each site, along with assessment of water and disturbances that are practical and realistic given ownership, regional water drainage and water-control infrastructure, and watershed needs (see e.g., Galatowitsch and van der Valk 1994).

Keith Frankki, refuge staff

Keith Frankki, refuge staff

SPECIFIC RECOMMENDATIONS FOR RESTORATION AND MANAGEMENT OPTIONS

IMPROVE THE PHYSICAL AND HYDROLOGICAL CHARACTER OF THE WILD RICE WATERSHED

1. *Slow and reduce surface water, sediment, and nutrient runoff into the Wild Rice River and through Tewaukon NWR.*

The historic Tewaukon NWR region was sustained by relatively slow surface water runoff across prairie moraine hills, through multiple small local drainages into the Wild Rice River, and into potholes and larger relict glacial lakes. Prairie grass cover captured and slowed surface water runoff on hills, which allowed water to infiltrate soils and recharge groundwater aquifers. Small drainages absorbed water under primarily wet prairie/meadow vegetation, and wetlands stored water along with using water for evapotranspiration. This suite of vegetation, soil, and topography attributes allowed the region to be effective "sponges" and "storage" regions for water, which sustained communities and mediated water runoff and downstream flooding in the Wild Rice and Red River system. When prairie grass cover was removed, surface water runoff was accelerated and did not infiltrate soils as readily. Tile drainage and small field ditches, along with the construction of the large Ditch No. 11 system, further reduced water retention in moraine slope soils and caused more water to move from these areas. Drainages became ditched and potholes were also ditched and became connected to accelerate water runoff and drain low depressions. Collectively, these land use changes led to more water running into and through Tewaukon NWR at an unnatural rapid rate and carrying higher loads of sediment and contaminants, which degraded the system. Specific actions to restore more natural soil, sediment, and nutrient runoff into Tewaukon NWR include:

- Delineate the specific sub-basin areas within the Wild Rice River watershed, including the LaBelle Creek drainage, that contribute the most, or are at the highest potential risk of contributing, sediment, nutrient, and surface water runoff into Tewaukon NWR using LiDAR-based stream index and soil erosion maps similar to those prepared for other northern RRV areas (e.g., see discussion in Heitmeyer et al. 2012).
- Target soil and water conservation practices to the above high erosion/runoff sub-basin areas, including USDA and USFWS private lands programs such as grassed waterways, terraces, restoration of grasslands, drop pipes, removal of tile drains, and removal or filling of field ditches.
- Restore natural drainage corridors including removal or modification of unnecessary ditches, roads, levees, rail lines, etc.

2. *Convert marginal, highly erosive, lands to native vegetation and wetlands*

Ultimately, the ecological integrity of the Tewaukon NWR region will be most enhanced and restored if complexes of native prairie and associated wetlands can be restored throughout the watershed. Targeting these prairie and wetland restorations to the most sensitive areas (as above) would be especially helpful as will the cumulative benefits of additional restored lands. Specific important programs will include:

- Promote acquisition of more USFWS WPAs and wetland and grassland easements. Also support targeted USDA land conservation programs including CRP and WRP for sensitive lands in the watershed.
- Identify and protect all remaining native prairie in the Tewaukon WMD and restore native prairie grasslands to highly erodible moraine hill slopes.
- Restore broad water flow corridors through natural moraine and pothole drainages by removing and filling ditches, restoring wide drainage slopes, and restoring wet prairie/ meadow vegetation.
- Restore multiple small wetland depressions in moraine hills by removing and filling drainage ditches and structures and protecting individual basin grassed depression watersheds.

RESTORE THE PHYSICAL AND HYDROLOGICAL INTEGRITY OF USFWS FEE-TITLE AND EASEMENT LANDS.

1. *Restore the physical and hydrological character of prairie pothole wetlands.*

The exact number and location of historical pothole wetland depressions on Tewaukon NWR Complex lands is not known, nor have all individual basins been inventoried as to size, watershed, and hydrological regime (USFWS 2000). Past attempts have been made to restore at least partial hydrology on some small wetland basins owned in fee-title in the Tewaukon NWR Complex lands by plugging or modifying drainage ditches in and from potholes. Further, more substantial modification of drainage ditches and installation of water-control structures have been conducted on a few large basins (USFWS, unpublished refuge annual narratives). Future efforts to restore the physical and hydrological characteristics of pothole wetlands on both fee-title and easement lands are desirable, however realistically, the only management capability the USFWS currently has on easement wetlands is to keep private landowners from burning, draining, and filling basins. In contrast, management on fee-title lands can actively seek to restore basins and management both surrounding upland and in-basin communities and water regimes. The below recommendations are primarily applicable to fee-title lands, with important opportunities for easement properties also listed.

- Complete an inventory of all pothole wetlands (on both USFWS fee-title and easement lands) to determine their individual local watersheds, source of water (surface runoff or groundwater discharge), type and degree of alterations including ditches and other dredge or fill activities or constructed features including water-control structures, and identification of the respective hydrological regimes ranging from small shallow ephemeral or seasonal basins to larger semi-permanently flooded basins. The first priority for pothole inventory should be fee-title lands because of the potential for active management and restoration. More detailed processing and analyses of LiDAR topographic information initially flown in 2008 should be conducted and used to assist pothole inventories and can potentially help identify water sources and surface water flow patterns
- Using the above inventory information make an assessment of whether the pothole wetland can function on its own, without modification or active water management. If so, active physical development or water manipulation of the basin, either on fee-title or easement lands, is not needed or desired.
- If a fee-title pothole basin is impaired and cannot function in a natural state in its current condition, first seek to restore the site so that it can function and support natural wetland communities on its own.Efforts should be made to conduct hydrological restorations of potholes on fee-title lands including removing, modifying, or plugging drainage ditches into, through, and out of the basins. Also, remove old tile drainage systems on uplands that drain and discharge groundwater into potholes. Other renovations may entail restoring the integrity of individual basin watersheds and the basin bathymetry if they have been highly altered. For example, some former small temporary and seasonal basins now have been incorporated into larger water management pools or

areas, and these sites should be evaluated to determine if the new larger pool is desired or whether the site can/should be restored to smaller less permanent wetland communities and basins.

- If a fee-title pothole does not have natural hydrological regimes (based on pothole type and location), attempt to manage water regimes (if water-control structures are present) on fee-title lands for natural seasonal and interannual water regimes and dynamics. The nature of the flooding and drying regimes should match its natural Type I-IV characteristics (see earlier discussion of pothole types). Some basins may require installation of water-control structures to allow storage and management of surface and groundwater discharge into the basin and/or to allow water to flow through the wetland in a natural way (e.g., in the Horse shoe Unit).
- Restore native vegetation on upland prairie slopes draining into potholes (both fee-title and easement lands).
- Develop native prairie buffer areas around all pothole wetlands to help reduce sediment runoff into the depressions (both fee-title and easement lands).

2. Restore the physical and hydrological character of larger relict glacial lakes/ larger wetland basins.

The Tewaukon and Sprague Lake units historically contained some relict glacial "lakes" including the larger Sprague, Mann, Hepi, White, and Tewaukon lakes. These large wetlands added unique resources to the region and were dominant features of the landscape that attracted not only wildlife, but also native and European people, to the area. Currently, all of these lakes have at least some water-control and levee structures that control water levels and Wild Rice River flow-through attributes and dynamics. True restoration of the historic physical and hydrological characteristics of some lakes such as Sprague and Tewaukon, is unlikely because of authorizing language that established the Tewaukon NWR, including the desire for permanent water levels to enhance and sustain a recreational fishery. Ideally, water management on the natural glacial lakes would seek to emulate seasonal and long-term dynamics of water level fluctuations and encourage natural dynamics of PPR wetland/lake communities such as alternating wet vs. dry periods at 20-30 year intervals (e.g., van der Valk 1989). While constraints exist to making these water management changes, the USFWS should continue to evaluate options to modify water movement into and from the lakes, evaluating changes in weir and stop-log structures, and changes in the management of spillway levels. These changes obviously must be carefully engineered to make sure adjacent non-USFWS lands are not adversely affected, but with the objective of effectively managing natural water and vegetation dynamics in the relict lake basin and to reduce downstream runoff and discharge into the Wild Rice River system. Future efforts to restore the historic lakes should include:

- Expand acquisition of Tewaukon NWR Complex lands that contain other historic glacial lake areas and their immediate watersheds.
- Evaluate all existing larger wetland impoundment areas, including former relict lake areas, to identify areas that are greatly modified from the natural community and hydrological regime state. In particular, sites that formerly contained wet prairie and pothole wetlands but that now are more permanently inundated because of water-control infrastructure and water management should be carefully considered for restoration back to the former community type and condition. As an example, the Maka, or Pool 3 area, historically was mostly a floodplain wet prairie community type that now is inundated by an expanded lake/shore area created by water-control infrastructure that was designed to create a larger lake/wetland area with more permanent flooding regimes, mostly to provide duck brood-rearing and migration habitat. If this area could be restored to a wet prairie/seasonal wetland complex, then it should be considered (if effects on downstream habitats and river flows are not considerable). Restoration of glacial lake areas, including those now artificially created by water-control infrastructure, should seek to restore natural topography and water flow patterns and corridors into the lake systems including reducing water discharge from potholes and other drainages into the lakes.

- Restore and manage former lake hydrology where possible.
- Manage water levels in the lakes for more natural seasonal and interannual water regimes and dynamics where possible. Long term climate and local precipitation data suggest ca. 20-30 year alternating wet and dry patterns of flooding and drying in these lakes.
- Restore natural land topography and native vegetation cover on prairie uplands that drain surface water and discharge groundwater into the lakes.

As stated earlier, ultimately restoring the physical and hydrological/community integrity of the large relict (and new artificial) lakes at Tewaukon NWR is desirable to not only improve ecological conditions on the refuge proper, but also to restore water flow patterns, regional water runoff and discharge regimes, former wet prairie and seasonal wetland communities, and contribute to reduced flooding problems downstream in the Red River basins.

RESTORE NATIVE VEGETATION COMMUNITIES

1. *Restore native mesic and wet-mesic tallgrass and mixed-grass prairie on upland moraine hill slopes.*

The highest elevations of moraine hill slopes on the Tewaukon NWR Complex historically contained mesic tallgrass and/or mixed-grass prairie. Some areas of the hill slopes contained sandy-type soils and supported plant species tolerant of this porous well-drained soil, while most slopes contained loam soils and typical tallgrass or mixed-grass and forb species. Lower elevations of side slopes, along with the bottom of moraine slopes, have higher ground water tables and receive local runoff, which helped support wet-mesic prairie assemblages. Older vegetation maps and botanical correlation from the HGM maps suggest little, if any, woody vegetation occurred in former prairie areas on the Tewaukon NWR Complex. The refuge CCP identified six prairie focus areas on Tewaukon NWR and three prairie focus areas on the Hartleben/Aaser, Gainor, and Gunness WPAs (USFWS 2000). In each of these areas the potential to protect, restore, and enhance continuous grassland patches of > 160 acres exists, and could protect and restore native species composition and structure. Restoration of these focus areas and other former prairie locations on the Tewaukon NWR Complex should seek to:

- Protect and enhance all areas where native prairie communities occur. Active management will be needed to maintain these remnant prairie patches and appropriate methods using fire, grazing, mowing, interseeding, and chemical treatments may be needed (Schroeder and Askerooth 2000). Where introduced smooth brome and Kentucky bluegrass has invaded native prairie stands, attempts should be made to restore the grass component back to native species.
- Convert most, if not all, agricultural cropland and non-native grassland, including planted DNC, that exists in former prairie habitats back to appropriate diverse native tallgrass or mixed-grass prairie communities based on topography, soils, and hydrology (see Fig. 22 for distribution of historical communities).
- Reseed upland moraine restoration sites with appropriate native prairie species mixes, using Fig. 22 as a guide to relative distribution of prairie community types. Further consider “sculpted seeding” where specific seeding mixes are matched to the topographic location of the site. For example, species mixes for the top of hills should reflect more mesic species composition, while seeding on lower hillslopes should contain species adapted to wetter soils and seasonal saturation. Also, seeding in eastern areas could attempt to plant more tallgrass community assemblages, while those in western areas could plant more mixed-grass assemblages.
- Control woody and invasive species encroachment into restored prairies with chemical, fire, and vegetation removal methods such as grazing and mowing. Prairie disturbance from fire and herbivory/mowing should match natural recurrence intervals for eastern North Dakota tallgrass prairie ecosystems.

2. *Restore wet prairie/meadow communities in moraine valleys and drainages and along the edges of wetlands.*

Bands of wet prairie/meadow communities were present in the drainages and valleys between moraine hills, wet areas along the Wild Rice River and tributaries, and upland edges of potholes and glacial lakes. These wet prairie areas provided critical grassland and meadow transition areas between wetland/river and true prairie habitats and provided important resources to many animal species. Management of this important habitat should include:

- Protect natural topography and hydrology of wet prairie/meadow sites to provide for shallow sheetwater flooding during spring runoff periods and heavy precipitation events.
- Identify all former areas of wet prairie/meadow and restore these sites to this community where possible (e.g., see prior discussion of the Pool 3 area) if they have been converted to other habitats or uses. In another example, water-control structures in the Pool B West area on the Sprague Unit now back water up onto former wet prairie habitats where water now is held and the site is converted to a Type IV wetland community. Ideally, water management would allow seasonal surface water flow-through on these sites to emulate a more natural seasonal “sheetflow” regime.
- Restoration of wet prairie sites should be cognizant of the potential invasion by reed canary grass, Canada thistle, and other invasive species and seek to minimize disturbances or conditions that might encourage their expansion. Much is unknown about the best methods to restore wet prairie in the Northern Great Plains region, and attempts to do so should be done in an adaptive manner using techniques and experiments suggested from other areas and should attempt to control invasive species as possible.

3. Restore natural wetland vegetation zones in prairie potholes.

Prairie potholes in the Tewaukon NWR Complex historically ranged from small shallow Type I ephemeral basins to deeper larger Type IV semipermanent basins. Restoration of the potholes should seek to emulate natural dynamics of water and vegetation by managing to:

- Restore natural topography of pothole basins where possible, but do not deepen or attempt to make small shallow basins deeper to hold more water or for longer periods.
- Allow potholes to seasonally dry according to historic type and encourage vegetation removal or disturbance in seasonally and long-term dry periods by fire and herbivory (or mowing).
- Evaluate water management capabilities on the over 30 semipermanently flooded wetlands on the Tewaukon and Sprague Lake units, and where possible restore or manage water regimes to emulate seasonal and long-term flooding and drying dynamics. Where possible, water management of the respective semipermanent wetlands could be rotated among years so that some of the wetlands would be in various stages of draw down or complete flooding during summer each year. This rotational management would help assure at least some habitat would be available in these wetlands in most years to support locally breeding waterbirds and other wetland wildlife. Within the rotational management, allow basins to periodically dry on at least a 20-30 year drought cycle.
- Discourage and control invasive species such as reed canary grass, Phragmites, and purple loosestrife into prairie potholes using chemical, mechanical, and other disturbance methods.
- Remove bait fish populations from pothole wetlands.

4. Restore natural wetland vegetation zones in larger relict glacial lakes.

The large relict glacial lakes on Tewaukon NWR historically contained extensive areas of wetland vegetation ranging from open water-aquatic species in deeper centers of the lake beds to wet meadow/wet prairie edges of the lakes that graded to tallgrass prairie on adjacent uplands. The distribution and extent of wetland vegetation zones likely varied substantially from dry to wet years with the degree and extent of water/soil saturation dictating distribution of specific assemblages. The important aspects of management of these lakes should:

- Restore natural topography of relict lakes where possible to recreate elevation gradients and heterogeneity that supported diverse wetland vegetation assemblages.

- Restore seasonal and long-term flooding and drying dynamics of larger lake basins where possible, and attempt to emulate alternating flood vs. drought patterns that dry at least the upper margins of lake basins on 20-30 year interval cycles.
- Emulate natural periodic disturbances of dense emergent species zones by burning or otherwise removing dense monotypic stands of cattail, hardstem bulrush, and invasive Phragmites.
- Control invasive plant species occurrence.
- Keep all fish (including fathead minnows) at a manageable level in refuge wetlands.

5. ***Maintain small bands of riparian woodland around parts of Lake Tewaukon, areas along the Wild Rice River, and along the LaBelle Creek corridor.***

Information about the extent of riparian woodland vegetation along creeks and larger relict lakes on the Tewaukon NWR Complex is limited (e.g., Hutton et al. 1920), but at least some of this habitat may have historically occurred along the Wild Rice River, LaBelle Creek, and some edges of Lake Tewaukon. Currently, some areas along LaBelle Creek and Lake Tewaukon support small areas of riparian woodland and they can be maintained. Evaluation efforts are needed to:

- Conduct evaluation of existing riparian woodlands to determine species composition, regeneration, survival, and age.
- Develop a restoration and management plan for these and other potential riparian woodland sites.

Keith Frankki, refuge staff

MONITORING AND EVALUATION

Future management of the Tewaukon NWR Complex should include regular monitoring and directed studies to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Past efforts to study and monitor key system attributes such as water and wetland distribution on the refuge and select studies of vegetation have been important to understanding changes in the Tewaukon NWR Complex system and developing recommendations for this HGM report (e.g., see references and information in Striffler 2013). Ultimately, the success in restoring and sustaining communities and ecosystem functions/values within the Tewaukon NWR Complex will depend on how well the physical and hydrological integrity of the regional watershed is protected and restored, and how historical natural key ecological processes and events, especially surface and groundwater water runoff and discharge of the Wild Rice River into and through Tewaukon NWR, can be restored or emulated by management actions. Uncertainty exists about the ability and effectiveness of making some system changes because of incomplete and fragmented refuge ownership, land use and soil and wetland drainage in the local watershed, and past infrastructure development of roads, ditches, levees, and water-control structures. Also, techniques for controlling or reducing introduced plant species, and restoration of some community species assemblages, such as upland tallgrass prairie, is not entirely known.

Whatever future management actions occur on Tewaukon NWR, activities should be done in an adaptive management framework where: 1) predictions about community response and water issues are made (e.g., increased area and productivity of shallow seasonal pothole wetlands) relative to specific management actions (e.g., restoring regular surface water) and then 2) follow-up monitoring is conducted to evaluate ecosystem responses to the action. Critical information and monitoring needs are identified below:

QUANTITY AND QUALITY OF SURFACE AND GROUNDWATER DISCHARGES AND RUNOFF THROUGHOUT THE WILD RICE RIVER WATERSHED

Ultimately, the capacity of the Tewaukon NWR Complex to sustain native communities and contribute to restoring the integrity of its unique tallgrass prairie/wetland ecosystem will depend on restoring natural patterns of surface and groundwater discharge, runoff, storage, and flow through in wetlands and native prairie. Specific monitoring and directed studies about hydrology of the Tewaukon NWR Complex are provided in the WRIA recently completed for the refuge (Striffler 2013). These and other monitoring efforts should:

- Develop watershed-scale monitoring and modeling of surface and groundwater discharge and storage amounts including quantifying water use on refuge lands.
- Document and clarify refuge water rights.
- Inventory and monitor agricultural tile drains and ditches including their location, maintenance, and discharges.
- Annual monitoring of water quality in the Ditch No. 11 system and Tewaukon NWR drainages and wetlands.

- Conduct bathymetric surveys of impoundments and monitor/document sedimentation amounts and rates.

RESTORING NATURAL WATER REGIMES AND WATER FLOW PATTERNS

This report suggests several physical and management changes to help restore some more natural topography, water flow, and flooding dynamics in prairie and wetland habitats. Most changes involve restoring at least some more natural water flow through natural drainages across prairie moraine hills and valleys, and into and through pothole and glacial lakes in a sheetflow manner and to manage depressions and impounded sites for more seasonally- and annually-dynamic flooding and drying regimes. The following monitoring will be important to understand effects of these changes if implemented:

- Annual monitoring of water management for refuge areas including source, delivery mechanism or infrastructure, extent and duration of flooding/drying, and relationships with non-refuge water and land uses. These data will also document how existing water drainage systems are used and maintained.
- Documentation of how water moves across floodplain areas, especially how surface water moves through the stair-step sequence of higher elevation pothole to lower elevation glacial lake wetlands.
- Evaluation of surface and groundwater interactions and flow across and through moraine hills onto wetland areas.
- Water flow patterns of water diverted from current or modified drainage systems into historic glacial lakes

LONG-TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

In addition to determining current distribution and dynamics of plant and animal species on the Tewaukon NWR Complex, long term survey/monitoring programs are needed to understand changes over time and in relation to management activities (e.g., Paveglio and Taylor 2010). Important survey/monitoring programs are needed for:

- Distribution and composition of major plant communities including expansion or contraction rates of introduced and invasive species.
- Responses of restored or enhanced grassland sites to control of introduced species and restoration of native prairie species assemblages.
- Responses of wetland habitats to changes in water management and seasonal distribution of surface water flows.
- Survival, growth, and regeneration rates of restored native prairie habitats.
- Presence and survival of fish in wetlands.
- Abundance, chronology of use, survival, and reproduction of key species such as dabbling ducks, marsh and shorebirds, grassland birds, small mammals, and amphibians and reptiles.

Jack Lalor, refuge staff

ACKNOWLEDGEMENTS

This HGM evaluation was administered through a contract between USFWS and Blue Heron Conservation Design and Printing LLC, Contract No. F11PD02908. Rob Bundy, former Project Leader for the Tewaukon NWR Complex, helped initiate the study and provided early administrative support for the project and important insights into past and current management of the refuge lands. Kent Sundeth and Jack Heisler provided administrative and biological support and review of the project during its completion. Kristine Askerooth, Jack Lalor, Jennifer Zorn, and Cami Dixon of the USFWS helped obtain information, maps, and annual narrative accounts for the refuge. Pete Striffler, USFWS Region 6 hydrologist, assisted with preparation of water resource information and he prepared the complimentary refuge WRIA report, including several figures and tables used in this HGM report. Wayne King, Region 6 Regional Biologist, provided administrative support for the project and he and Mike Artmann helped coordinate meetings for the project along with regional office and refuge staff review of report drafts. Karen Kyle of Blue Heron Conservation Design and Printing LLC administered the contract for the project and provided assistance with the analyses of data and geographical information, preparation of report drafts, and publication of the final report.

Jack Lalor, refuge staff

Al Sapa, USFWS

LITERATURE CITED

Axelrod, D.I. 1985. Rise of the grassland biome, central North America. Botanical Review 51:163-201.

Bailey, V. 1926. A biological survey of North Dakota. I. Physiography and life zones. II. The mammals. U.S. Department of Agriculture, Bureau of Biological Survey, Washington, DC.

Baker, C.H. Jr. 1967. Geology and ground water resources of Richland County: Part I – Geology. North Dakota Geological Survey Bulletin 46.

Baker, C.H. Jr. and Q.F. Paulson. 1967. Geology and ground water resources Richland County, North Dakota: Part III Groundwater resources. North Dakota Geological Survey Bulletin 46.

Bennet, F., E.L. Worthen, R.E. Willard, and E.B. Watson. 1908. Soil survey of Richland County, North Dakota. Field Operations of the Bureau of Soils.

Bluemle, J.P. 1979. Guide to the geology of Southeastern North Dakota – revised edition. Educational Series 3, North Dakota Geological Survey.

Bluemle, J.P. 1988. Guide to the geology of Southeastern North Dakota – revised edition. Educational Series 18, North Dakota Geological Society.

Bluemle, J.P. and L. Clayton. 1982. Geologic time in North Dakota. Educational Series 14, North Dakota Geological Survey.

Bragg, T.B. 1982. Seasonal variation in fuel and fuel consumption by fires in a bluestem prairie. Ecology 63:7-11

Bragg, T.B. and L.C. Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. Journal of Range Management 29:19-23.

Brown, D.E., T.C. Brennan, and P.J. Unmack. 2007. A digitized biotic community map for plotting and comparing North American plant and animal distributions. Canotia 3:1-12.

Carlson, A.E. 2006. Dynamics of the Laurentide Ice Sheet. Ph.D. Dissertation, Oregon State University.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC.

Crosbie, R., B.Scanlon, F. Mpelasoka, R.Reedy, J.Gates and L. Zhang. 2013. Potential climate change effects on groundwater recharge in the High Plains Aquifer. Glen Osmand SA: CSIRO Accepted article, DOI:10.1002/WRCR.20292.

Dahl, T. 1990. Wetland losses in the United States 1790's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T. 2011. Status and trends of wetlands in the conterminous United States 2004-2009. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Denevan, W.M. 1992. The Pristine Myth: The landscape of the Americans in 1492. Annals of the Association of American Geographers 82(3):369-385.

Dolin, E.J. 2010. Fur, fortune and empire – the epic history of the fur trade in North America. W.W. Norton and Company, New York.

Epp, H. and I. Dyck. 2002. Early human-bison population interdependence in the Plains Ecosystem. Great Plains Research: A Journal of Natural and Social Sciences. Paper 615.

Fischman, R.L. and R.S. Adamcik. 2011. Beyond trust species: the conservation potential of the National Wildlife Refuge System in the wake of climate change. Natural Resources Journal 51:1-33.

Fitting, J.E. 1970. The Archaeology of North Dakota: A guide to the prehistory of the Great Lakes Region. American Museum of Natural History, The Natural History Press, Garden City, New York. Pages 7-33.

Galatowitsch, S.M. and A.G. van der Valk. 1994. Restoring prairie wetlands: an ecological approach. Special publication of Ducks Unlimited's Institute for

Wetland and Waterfowl Research. Iowa State University Press, Ames, IA.

Gannon, J.J., C.T. Moore, T.L. Shaffer, and Flanders-Wanner, B. 2011. An adaptive approach to invasive plant management on Fish and Wildlife Service owned native prairies in the prairie pothole region. University of Georgia, Athens, GA.

Gantt, L.K. 1980. The presettlement vegetation of Richland County, North Dakota. M.S. Thesis, North Dakota State University, Fargo, ND.

GEI Consultants, Inc. 2002a. Cutler Marsh Dam National Inventory of Dams No. ND 00399 Low Hazard Formal SEED Inspection Report. Englewood, CO.

GEI Consultants, Inc. 2002b. Maka Pool Dam National Inventory of Dams No. ND 00400 Low Hazard Formal SEED Inspection Report. Englewood, CO.

GEI Consultants, Inc. 2002c. River Pool Dam National Inventory of Dams No. ND 00401 Low Hazard Formal SEED Inspection Report. Englewood, CO.

Goden, V. and N. Goden. 2002. Fargo, North Dakota Climate. Scientific Services Division, Central Region, Kansas City, MO.

Heidel, B.L. 1986. Bluestem prairie inventory in the Red River Valley, North Dakota. *In* G.K. Chambey and R.M. Pemble, editors, The prairie: past, present, and future. Proceedings of the Ninth North American Prairie Conference. Tri-College University Center for Environmental Studies, North Dakota State University, Fargo, ND.

Heitmeyer, M.E. 2007. Conserving lacustrine and palustrine natural communities. Missouri Natural Areas Newsletter 4(1):3-5.

Heitmeyer, M.E., R.L. Esser, J.D. Eash and B.J. Newman. 2012. Hydrogeomorphic evaluation of ecosystem restoration and management options for Hamden Slough National Wildlife Refuge. Greenbrier Wetland Services Report No. 12-01. Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

Heitmeyer, M.E. and C.M. Aloia. 2013. Hydrogeomorphic evaluation of ecosystem restoration and management options for Monte Vista National Wildlife Refuge. Greenbrier Wetland Services Report No. 13-02. Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

Heitmeyer, M.E., L.H. Fredrickson, M.K. Laubhan, F.A. Nelson, D.G. Pogue, D.L. Helmers and W. King. 2013. Wetland design and development. Pages 69-120 *in* J.T. Anderson and C.A. Davis, editors. Wetland Techniques, Volume 3. Springer, New York.

Heitmeyer, M.E., C.M. Aloia and P.W. Burck. 2014. Hydrogeomoprhic evaluation of ecosystem restoration and management options for Aransas National Wildlife Refuge. Greenbrier Wetland Services Report No. 14-01. Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

Higgins, K.F. 1984. Lightning fires in North Dakota grasslands and in pine-savanna lands of South Dakota and Montana. Journal of Range Management 37(2):100-103.

Hoberg, T. and C. Gause. 1992. Reptiles and amphibians of North Dakota. North Dakota Outdoors 55(1):7-19.

Holzkamm, T.E. 1981. Traders of the plains – the European fur trade and the westward expansion of the Dakota or Sioux Indians. M.A. Thesis, McMaster University, Hamilton, Ontario.

Hulbert, L.C. 1986. Fire effects on tallgrass prairie. Pages 138-142 *In* G.K. Chambey and R.M. Pemble, editors, The prairie: past, present, and future. Proceedings of the Ninth North American Prairie Conference. Tri-College University Center for Environmental Studies, North Dakota State University, Fargo, ND.

Hutton, F.Z., B.H. Hendrickson, M. Thomas and S. Buster. 1920. Soil Survey of Sargent County, North Dakota. U.S. Department of Agriculture. U.S. Government Printing Office, Washington, DC.

Isenberg, A.C. 1993. Indians, whites, and the buffalo: an ecological history of the Great Plains, 1750-1900. Ph.D. Dissertation, Northwest University, Evanston, IL.

Kantrud, H.A., J.B. Millar and A.G. van der Valk. 1989. Vegetation of wetlands of the prairie pothole region. Pages 132-187 *in* A.G. van der Valk, editor. Northern prairie wetlands. Iowa State University Press, Ames, IA.

Kehew, A.E. and W.M. Boettger. 1986. Depositional environments of buried-valley aquifers in North Dakota. Ground Water 24(6):728-734.

Key, J.P. 1982. Craniometric relationships among Plains Indians: culture-historical and evolutionary implications. University of Tennessee, Knoxville, TN.

Kirby, R.E., S.J. Lewis and T.N. Sexson. 1988. Fire in North American wetland ecosystems and fire-wildlife relations: an annotated bibliography. U.S. Fish and Wildlife Service, Office of Information Transfer, Fort Collins, CO.

Klimas, C. E. Murray, T. Foti, J. Pagan, M. Williamson and H. Langston. 2009. An ecosystem restoration model for the Mississippi Alluvial Valley based on geomorphology, soils, and hydrology. Wetlands 29:430-450.

Krapu, G.L. 1996. Effects of a legal drain clean-out on wetlands and waterbirds: a recent case history. Wetlands 16:150-162.

Larson, G. and R. Schaetzl. 2001. Review: origin and evolution of the Great Lakes. Journal of Great Lakes Research 27:518-546.

Lounsberry, C.A. 1919. Early history of North Dakota: essential outlines of American history. Liberty Press, Washington D.C.

Mayewski, P.A. 1981. The last Wisconsin ice sheets in North America. Pages 67-128 *in* G.H. Denton and T.J. Hughes, editors. The last great ice sheets. John Wiley and Sons, New York.

Meretsky, V.J., R.L. Fischman, J.R. Karr, D.M. Ashe, J.M. Scott, R.F. Noss and R.L. Schroeder. 2006. New directions in conservation for the National Wildlife Refuge System. Bioscience 56:135-143.

Miller, J.E. and D.L. Frink. 1984. Changes in flood response of the Red River of the North Basin, North Dakota-Minnesota. U.S. Geological Survey Water-Supply Paper 2243.

Millett, B., W.C. Johnson, and G. Guntenspergen. 2009. Climate trends of the North American prairie pothole region 1906-2000. Climatic Change 93:2443-267.

Moberg, W.W. 1952. Original grasslands of North Dakota. Bimonthly Bulletin, XIV(6). 240 pages.

Murkin, H.R., A.G. van der Valk and W.R. Clark, editors. 2000. Prairie wetland ecology – the contributions of the Marsh Ecology Research Program. Iowa State University Press, Ames, IA.

Paveglio, F.L. and J.D. Taylor. 2010. Identifying refuge resources of concern and management priorities: a handbook. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Pemble, R.H. 1995. A survey of native prairie remnants and prairie species of special interest in the vicinity of the Hamden Slough National Wildlife Refuge, Becker County, Minnesota. Report prepared for U.S. Fish and Wildlife Service. Department of Biology, Moorhead State University, Moorhead, MN.

Proce, C.J., R.W. Ritzi, D.F. Dominic, and Z. Dai. 2004. Modeling multiscale heterogeneity and aquifer interconnectivity. Ground water 42:658-670.

Pyne, S.J. 1994. Historical fire: the coming of fire to America. *In* Proceedings of the role of fire in ecosystem management workshop. National Advance Resource Technology Center, Marana, AZ.

Rannie, W.F. 1998. A Survey of Hydroclimate, Flooding, and Runoff in the Red River Basin Prior to 1870. Geological Survey of Canada.

Samson, F.G. and F.L. Knopf, editors. 1996. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Covelo, CA.

Schroeder, R.L. and K.L. Askerooth. 2000. A habitat-based approach to management of tallgrass prairie at the Tewaukon National Wildlife Refuge. U.S. Department of the Interior, U.S. Geological Survey Technical Report 2000-0001, Fort Collins, CO.

Sims, P.L. 1991. Grasslands. Pages 265-286 *in* M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, New York.

Smeins, F.E. 1967. The wetland vegetation of the Red River Valley and drift prairie region of Minnesota, North Dakota, and Manitoba. Ph.D. Dissertation, University of Saskatchewan, Saskatoon.

Steinauer, E.M. and S.L. Collins. 1996. Prairie ecology – the tallgrass prairie. Pages 39-52 *in* F.B. Samson and F.L. Knopf. Prairie conservation, preserving North America's most endangered ecosystem. Island Press, Washington, DC.

Stewart, R.E. and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildlife Service, Resource Publication No. 92.

Striffler, P.S. 2013. Water Resource Inventory and Assessment – Tewaukon National Wildlife Refuge. U.S. Fish and Wildlife Service, Lakewood, CO.

Soil Conservation Service. 1964. Soil Survey of Sargent County, ND. U.S. Department of Agriculture, Soil Conservation Service.

Steckel, R.H. and J.M. Prince. 2001. Tallest in the world: native Americans of the Great Plains in the nineteenth century. The American Economic Review 91:287-294.

Strobel, M.L. 1996. Hydrologic factors affecting the discharge of ground water in the Red River of the North Basin, Northeastern North Dakota. Ph.D. Dissertation, University of North Dakota, Grand Forks, ND.

Theiling, C.H., D.A. Bettis, III and M.E. Heitmeyer. 2012. Hydro-geomoprhic classification and potential vegetation mapping for Upper Mississippi River bottomland restoration. *In* T. Piacentini and E. Miccadei, editors. Studies on environmental and applied geomorphology, InTech, Rijeka, Croatia.

Thompson, D.G. and L.L. Joos. 1975. Soil survey of Richland County and Sheyenne National Grassland area of Ransom County, North Dakota. U.S. Department of Agriculture, Soil Conservation Service in cooperation with the North Dakota Agricultural Experiment Station.

U.S. Fish and Wildlife Service. 1962. Master plan: Tewaukon National Wildlife Refuge.

U.S. Fish and Wildlife Service. 1991. Hamden Slough National Wildlife Refuge Concept Plan. U.S. Fish and Wildlife Service, Minneapolis, MN.

U.S. Fish and Wildlife Service. 1999. Fulfilling the promise: the National Wildlife Refuge System. U.S. Fish and Wildlife Service, Arlington, VA.

U.S. Fish and Wildlife Service. 2000. Tewaukon National Wildlife Refuge: Comprehensive Conservation Plan, Cayuga, ND.

U.S. Fish and Wildlife Service. 2001. Fish and Wildlife Service, Refuge management manual, part 601, National Wildlife Refuge System. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

U. S. Global Change Research Program. 2012. Global climate change impacts in the United States. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/great-plains.

Upham, W. 1895. The glacial Lake Agassiz. U.S. Geological Survey Volume XXV, U.S. Government Printing Office, Washington, DC.

van der Valk, A.G., editor. 1989. Northern prairie wetlands. Iowa State University Press, Ames, IA.

van der Valk, A.G. and C. B. Davis. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59:322-335.

Wedel, W. 1961. Prehistoric man on the Great Plains. University of Oklahoma Press, Norman, OK.

Winter, T.C. 1989. Hydrological studies of wetlands in the northern prairie. Pages 16-54 *in* A.G. van der Valk, editor. Northern prairie wetlands. Iowa State University Press, Ames, IA.

Winter, T.C., R.D. Benson, R.A. Engberg, G.J. Wiche, D.G. Ermerson, O.A. Crosby, And J.E. Miller. 1984. Synopsis of ground-water and surface-water resources of North Dakota. U.S. Geological Survey Open-File Report 84-732.

Yansa, C.H. 2007. Lake records of Northern Plains Paleoindian and Early Archaic environments: the "Park Oasis" Hypothesis. Plains Anthropologist 52:109-144.